SEWAGE AND INDUSTRIAL WASTES

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

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Sewage Chlorination Statistics—Thoman and Jenkins

Fungi in Activated Sludge—Cooke and Ludzack

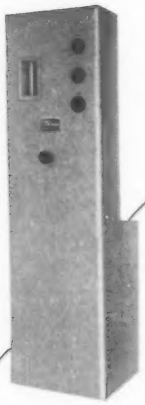
Operator's Corner—Operator Ingenuity, Street Safety

1958 Meeting Report

1958 ANNUAL INDEX

DECEMBER 1958—VOL. 30, No. 12

POSITIVE CONTROL OF MATERIALS IN MOTION



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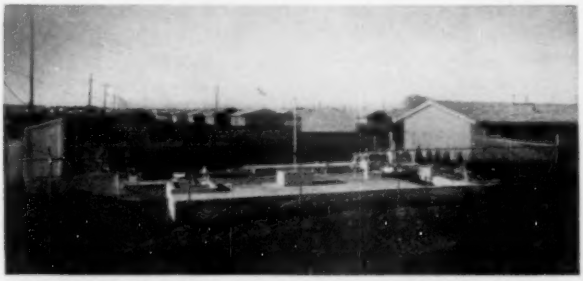

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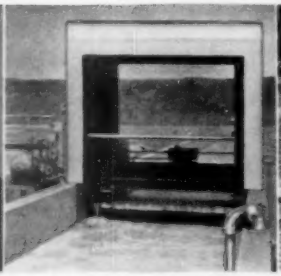

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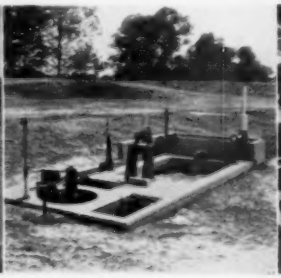

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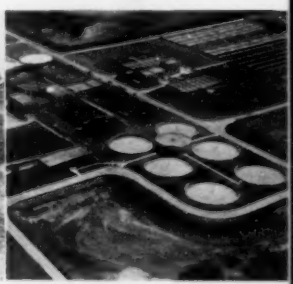

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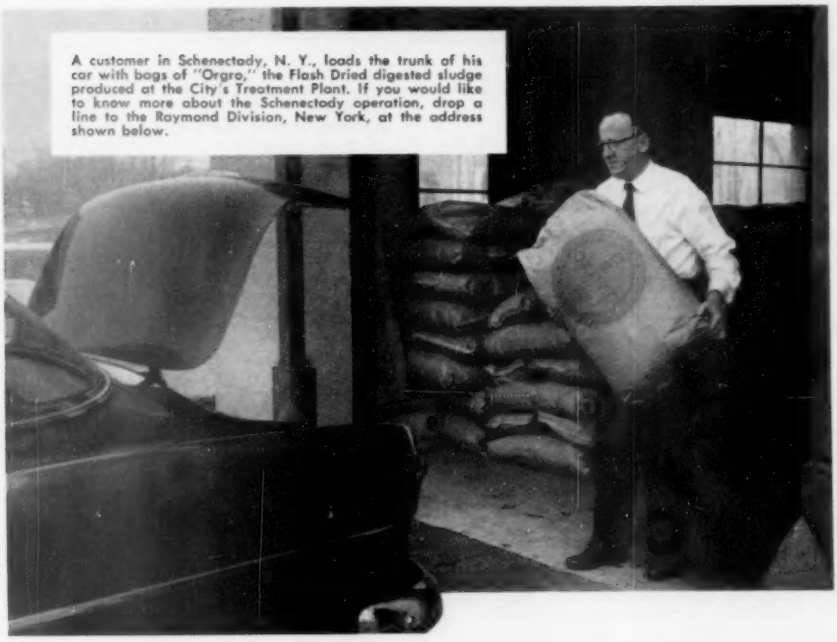

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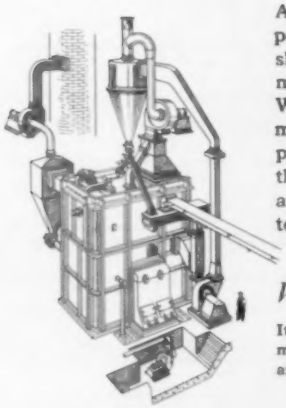

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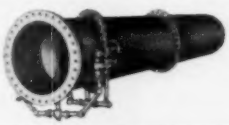
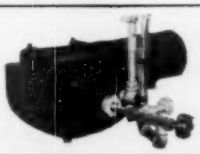
NORMAL SEWAGE, SLUDGE, TRADE WASTES		TYPE VTJ—SINGLE TAP VENTURI TUBES Single taps at main and throat have bayonet-type valve for fast cleaning. Absence of pressure belts prevents clogging. Inspection opening at throat. BULLETIN 005
NORMAL SEWAGE, SLUDGE, TRADE WASTES		TYPE VS—FOUR TAP VENTURI TUBES Four cleaning valves at main and throat can be operated manually, by air, or hydraulically to keep piezometer holes clear for top accuracy. Two hand holes on each pressure belt and inspection opening at throat. BULLETIN 005
LOW-VELOCITY SEWAGE, HEAVY WASTES		TYPE VE—ELLIPTICAL VENTURI TUBES Developed specifically to accurately measure low-velocity sewage, sludge and heavy trade wastes—under low pressures. *Flat top* prevents air binding. *Flat bottom* is self-scouring. Inspection opening at throat. BROCHURE
LOW-HEAD SEWAGE, SLUDGE, TRADE WASTES		TYPE S—PARABOLIC FLUMES Full 20:1 range for open flows. Accuracy ±2%. Flanged, bell or spigot inlet for 6 to 36" lines. Integral sediment trap, piezometer reamer, gauge glass, direct-reading flow scale. BULLETIN 801

MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Time*
New York Sewage and Industrial Wastes Assn.	Park Sheraton Hotel New York, N. Y.	Jan. 22–23, 1959
Utah Sewage and Industrial Wastes Assn.	Univ. of Utah Salt Lake City, Utah	Feb. 3, 1959
Texas Water and Sewage Works Assn.	Texas A & M College College Station, Tex.	Mar. 1–6, 1959
Mississippi Sewage and Industrial Wastes Assn.	Robert E. Lee Hotel Jackson, Miss.	Mar. 6, 1959
New Jersey Sewage and Industrial Wastes Assn.	Traymore Hotel Atlantic City, N. J.	Mar. 11–13, 1959
Louisiana Conf. on Water Supply and Sewerage	Louisiana State Univ. Baton Rouge, La.	Mar. 18–20, 1959
Montana Sewage and Industrial Wastes Assn.	Jordan Hotel Glendive, Montana	Apr. 9–11, 1959
Virginia Industrial Wastes and Sewage Works Assn.	The Mimslyn Luray, Va.	Apr. 13–14, 1959
Arizona Sewage and Water Works Assn.	Hi-Way House Hotel Phoenix, Ariz.	Apr. 16–18, 1959
Kansas Sewage and Industrial Wastes Assn.	Baker Hotel Hutchison, Kans.	Apr. 22–24, 1959
California Sewage and Industrial Wastes Assn.	Lafayette Hotel Long Beach, Calif.	Apr. 29– May 2, 1959

THIRTY-SECOND ANNUAL MEETING

Federation of Sewage and Industrial Wastes Associations
Host—Sewage and Industrial Wastes Section,
Texas Water and Sewage Works Association
Statler Hilton Hotel, Dallas, Texas
October 12–15, 1959

IN THE MINIMUM SPACE

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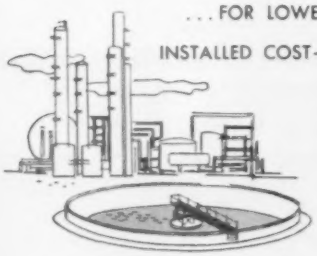

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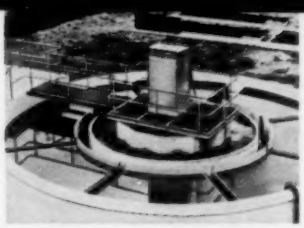

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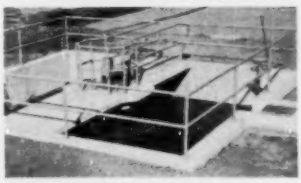

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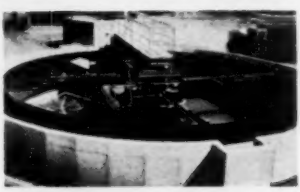

SEDIFLOTOR®

clarifiers enable both sedimentation and flotation in one compact unit

Where space is limited and clarification a must, this air flotation unit is ideal for removal of both flotable materials and settleable solids. BULLETIN 6051

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Full variety with many exclusive features available.

Lime slakers, dry, solution and slurry-feed types, available for either constant or variable-rate operation.

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INFILCO KNOWS HOW to help you control pollution, water reclamation and materials loss problems.

No other line of waste treatment equipment is so complete as INFILCO's—none so advanced in method and design. There are many other units in addition to typical examples illustrated above.

INFILCO engineers know how to help solve your waste-water disposal problems with knowledge gained from many years of specialized experience in industrial waste treatment. Write today for bulletins of interest to you. Inquiries are invited on all waste-water treatment problems.

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Field offices throughout the United States and in foreign countries

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ABILITY . . .

6 reasons why Cast Iron Pipe is #1 choice of U. S. A.

1. HIGH FLOW CAPACITY . . . Cement lined cast iron pipe and fittings will not tuberculate . . . delivers a full flow for the life of the pipe.
2. LONG LIFE . . . 42 North American cities are still using cast iron water mains laid 100 years and more ago. Hundreds more have passed the 50 year mark.
3. BEAM STRENGTH . . . Cast Iron Pipe is inherently tough . . . stands up under heavy traffic load, soil displacement and disturbance.
4. EXTERNAL LOAD RESISTANCE . . . 6" Class 150 Pipe withstands a crushing load of 17,900 pounds per foot . . . nearly 9 tons.
5. CORROSION RESISTANCE . . . Cast Iron Pipe effectively resists corrosion . . . vital factor in its long life and dependability.
6. TIGHT JOINTS . . . A full range of leak-proof, low cost, easy-to-assemble joints for pipe and fittings are available for all conditions.

THE MAN WHO CHOOSES CAST IRON PIPE TODAY WON'T PAY FOR IT AGAIN TOMORROW!

CAST IRON

Cast Iron Pipe Research Association
Thos. F. Wolfe, Managing Director
Suite 3440, Prudential Plaza, Chicago 1, Ill.

MODERNIZED **cast iron**

NOT PROBABILITY!

Cast Iron Pipe's record of maintaining high flow capacity throughout its long life is FACT not FICTION!

Carrying capacity without strength is like running a rickety car with a powerful engine . . . sooner or later it will shake apart.

Why choose between high flow, strength and long life when cast iron pipe gives you *all* of them?

Specify America's #1 pipe and your water system will serve long after the bond issue is retired.

*Here is the proof!

FLOW FACTORS FOR CEMENT LINED CAST IRON PIPE

LOCATION	SIZE	TEST SECT. IN FEET	VELOCITY F.P.S.	AGE YEARS	W & H "C" FACTOR
Bowling Green, Ohio	20"	45,592	0.7-2.4	New	142.5
Chicago, Illinois	36"	7,200	2.6-3.6	New	147
New Orleans, La.	12"	39,650	1.2-2.9	New	141
Cordor, Mo.	8"	21,350	0.9-2.3	New	143
Univ. of Illinois	8"	400	3.14	New	150
Concord, New Hamp.	14"	500	1.7-2.2	New	151
Concord, New Hamp.	12"	500	2.0-3.4	11	142
West Palm Beach, Fla.	12"	500	3.6-5.4	15	139.5
Greenville, S. C.	30"	87,376	2.4-2.7	12	148.5
Corpus Christi, Tex.	30"	65,641	1.1-1.8	6	146
Summerville, S. C.	8"	500	1.98-2.43	13	142.5
Champaign, Illinois	16"	3,920	3.1-5.6	22	139.3

*Available upon request. Booklet containing flow test and tables on Cast Iron Pipe.

pipe FOR MODERN WATER WORKS

INERTOL PAINTS PROTECT
MULTI-MILLION-DOLLAR MIAMI PLANT

Partial view of new Sewage Treatment Plant, City of Miami, Florida . . . buildings, tanks, equipment . . . protected with Inertol Paints.

On Virginia Key, three miles off the Florida mainland, stands Miami's new $10-million sewage treatment plant, heart of the new $27-million sewerage system. To protect this costly installation against the ravages of corrosion, fumes, condensation, salt air, heat and humidity, rugged Inertol coatings were specified (Consulting Engineers: Metcalf and Eddy, Boston, Massachusetts).

Buildings, the four 105′-diameter digesters, the towering chimney structure and other surfaces are protected economically and efficiently with *Ramuc® Masonry Paint*. Thousands more square feet of area of this 47-MGD plant are guarded with other corrosion-resistant, attractive Inertol coatings.

Buy Inertol paints direct from the manufacturer. Shipment within three days from our plant, or from nearby warehouse stocks. Write for free booklet S-754, "Principal Types of Protective Coatings."

SPECIFICATIONS FOR RAMUC MASONRY PAINT

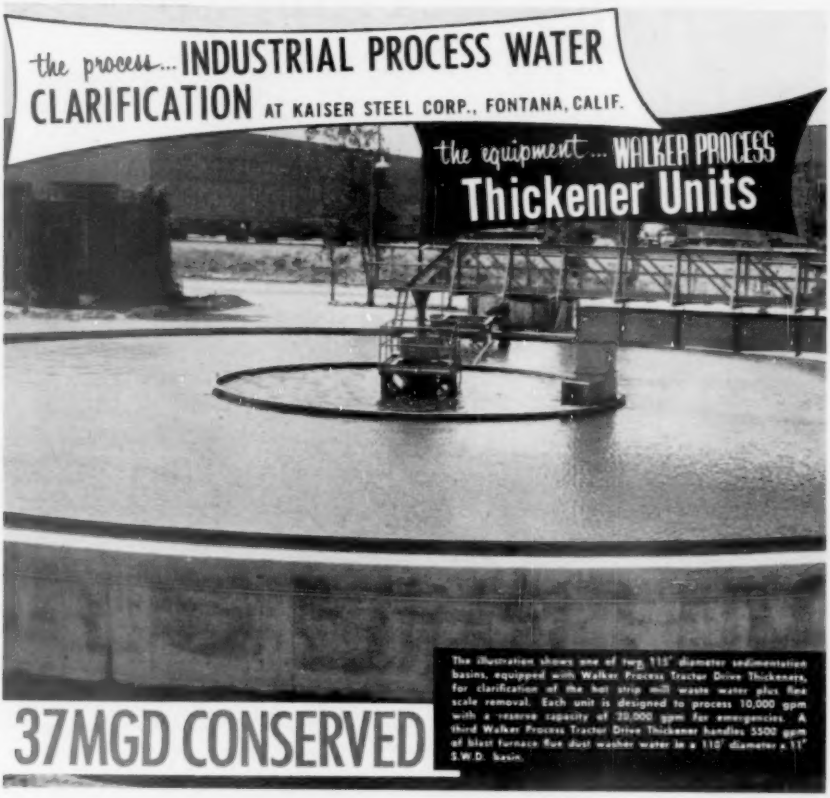
A chlorinated natural rubber-base paint in color. Flat finish. For exterior above-grade masonry. Unaffected by masonry lime. Highly weather- and fume-resistant. No mottling.

Colors: Color Chart 563.
No. of coats: Two (if semi-gloss finish desired, specify semi-gloss type for top coat).
Coverage: 150-250 sq. ft. per gal. per coat, depending on surface texture.
Approx. mil thickness per coat: 1.5.
Drying Time: 24 hours.
Primer: None. However, to minimize efflorescence, specify one coat of Pluvol® as primer.
Thinners: Inertol Thinner 2000-A for brushing; 2000, for spraying.
Application: Brushing: As furnished. Spraying: First coat must be brushed. For spraying, add sufficient Thinner 2000 (10-15%).

Inertol®

*Registered Trademark. *Write for information on Pluvol, invisible silicone water-repellent.*
A complete line of quality coatings for sewage, industrial wastes and water plants.

INERTOL CO., INC.
482 Frelinghuysen Ave., Newark 12, N. J. • 27-H South Park, San Francisco 7, Calif.


the process... INDUSTRIAL PROCESS WATER CLARIFICATION AT KAISER STEEL CORP., FONTANA, CALIF.
the equipment... WALKER PROCESS Thickener Units
The illustration shows one of two, 115' diameter sedimentation basins, equipped with Walker Process Tractor Drive Thickeners, for clarification of the hot strip mill waste water plus flue scale removal. Each unit is designed to process 10,000 gpm with a reserve capacity of 20,000 gpm for emergencies. A third Walker Process Tractor Drive Thickener handles 5500 gpm of blast furnace flue dust washer water in a 110' diameter x 11' S.W.D. basin.
37MGD CONSERVED

Waste water treatment at Kaiser Steel Corporation's Fontana, California Works includes facilities for handling blast furnace flue dust washer water and hot strip mill process water. A combined total of 37 MGD indicates the importance of waste water treatment—from a conservation standpoint as well as operating economy.

Heavy fines and particles, encountered in steel mill wastes, require equipment designed to move literally tons of abrasive sludge with as little maintenance as possible. Walker Process Tractor Drive Thickeners especially suit these conditions. The drive at the periphery of the basin utilizes the bridge as a lever to exert high rotational force with a minimum of gear reducer effort. This feature also permits the use of simpler, more accessible gear reducers which simplify maintenance and adds years to the service life of the unit.

In addition to Tractor Drive Thickeners, Walker Process manufactures sludge collector units for all types and sizes of applications—circular, rugged, center drive units, either pier or bridge supported and rectangular mechanisms.

Write for information on equipment for the treatment of municipal water and sewage and industrial liquids.

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WALKER PROCESS EQUIPMENT INC.
FACTORY • ENGINEERING OFFICES • LABORATORIES
AURORA, ILLINOIS

Now! Transite Sewer variety

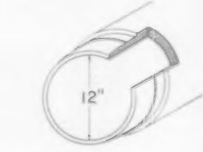
Transite's Ring-Tite® Coupling is designed for high-speed assembly . . . presents no problem in joining lengths of varying crushing strengths or diameters.

CLASS 1500—

CLASS 2400—

CLASS 3300—

CLASS 4000—



CLASS 5000—

Transite Sewer Pipe now classed by Standardized Crushing Strengths

Based on A.S.T.M. 3-edge bearing method (strength in lbs. per lineal foot)

Size Inches	Class 1500	Class 2400	Class 3300	Class 4000	Class 5000
6	1500	2400	3300	—	—
8	1500	2400	3300	—	—
10	1500	2400	3300	4000	5000
12	1500	2400	3300	4000	5000
14	—	2400	3300	4000	5000
16	—	2400	3300	4000	5000
18	—	2400	3300	4000	5000
20	—	2400	3300	4000	5000
24	—	2400	3300	4000	5000
30	—	—	3300	4000	5000
36	—	—	—	4000	5000

Pipe is available in a wide of new crushing strengths

Progressive new concept permits greater efficiency in sewer design . . . reduces overall costs through closer matching of crushing strengths to needs!

HERE'S the biggest sewer pipe advance in years! In a revolutionary move, Johns-Manville introduces five new sewer pipe classifications to greatly simplify accurate sewer pipe specification . . . permitting overall cost saving to a degree never before possible.

Through improved manufacturing methods, Johns-Manville brings you Transite Sewer Pipe in a variety of the more widely needed crushing strengths: 1500, 2400, 3300, 4000, and 5000 lbs. . . . in 11 different diameters ranging from 6" to 36" (*see chart*).

Permits greater efficiency in system design. To the engineer, the new Transite crushing strengths mean new ease in achieving greater efficiency in sewer design. For now he can plan pipe layouts as he has always wanted—selecting pipe on the basis of depth of cut, width of trench, type of soil and manner of bedding. The result: far greater overall economy through use of more realistic safety factors . . . reduction in the need for overdesign . . . with costly concrete encasement and cradling needed in fewer areas.

Let us send you TR-94A, Sewer Design Flow Chart and DS-366, Transite Specifications. Write Johns-Manville, SI, Box 14, New York 16, New York. In Canada, Port Credit, Ontario.

JOHNS-MANVILLE

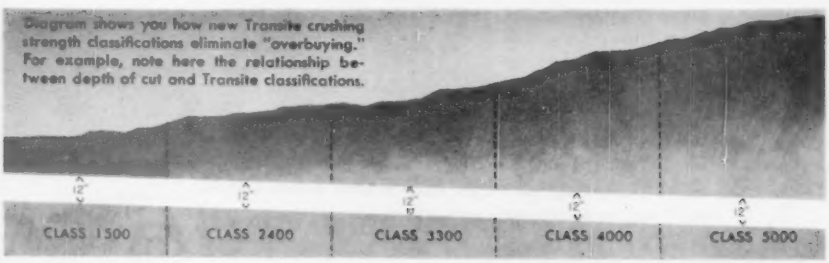


Diagram shows you how new Transite crushing strength classifications eliminate "overbuying." For example, note here the relationship between depth of cut and Transite classifications.
CLASS 1500
CLASS 2400
CLASS 3300
CLASS 4000
CLASS 5000

Thirty more miles of concrete pipe were added to Milwaukee's sewer system in 1957, most of it 8" I.D.

In Milwaukee . . .

the entire residential sewer system is concrete pipe

Concrete pipe was chosen by Milwaukee in 1923 for its new residential sewage collecting system. All submains and mains have been included in this continuing program. Performance record? Not a single failure attributed to the pipe where it has served residential use.

That's because concrete pipe has uniformly high strength right from the start . . . and because concrete, by its very nature, grows stronger year by year.

Milwaukee chose concrete pipe because it meets the requirements of uniformity of strength—strength to carry all the loads—durability, availability and low initial cost.

Add maximum hydraulic capacity and long life. Put all these advantages together and it's easy to see why more and more municipalities are finding concrete is the answer to low-cost, trouble-free pipelines. Write for free literature, "*Concrete Sewers*," distributed only in the United States and Canada.

FOR ALL MODERN PIPELINES
concrete

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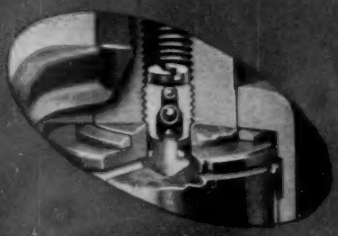
Dept. 12-76, 33 West Grand Avenue, Chicago 10, Ill.

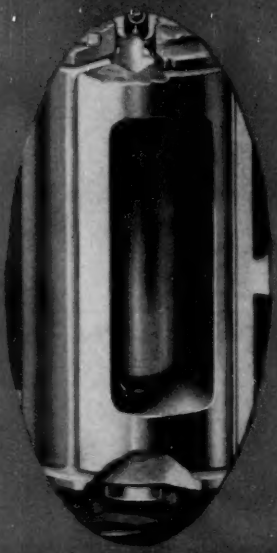
A national organization to improve and extend the uses of concrete

In the spots that count... Homestead Valves are

LEAKPROOF



Reinforced Teflon* seal lubricant seal



Controlled pressurized lubricant seal

Lower cost per year valve service is guaranteed by Homestead Lubricated Plug Valves. These are the features that make them leakproof and extend their useful life . . . reinforced Teflon* head seal, double ball and lubricant sealed check valve, and their exclusive controlled pressurized lubricant seal. Homestead's controlled lubricating system forces a chemical film over all sealing surfaces at more than 300 pounds pressure. In addition, it prevents sticking, by its piston-like movement of the plug during each lubrication. See how Homestead fills your valve needs.

Write today for Reference Book 39, (Section 5), which gives complete information on Homestead Lubricated Plug Valves.

*DuPont registered trademark.

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seals right · · ·

Lay Tyton Joint® pipe and relax

Tyton Joint pipe is sealed tight . . . water-tight . . . by a specially designed rubber gasket that is compressed by the entering pipe.

Tyton Joint pipe is easy to work with, too. So easy even "green" crews become experts in minutes. No bell holes, no pouring snake, no caulking equipment . . . no nuts or bolts to

U.S. cast iron PIPE

FOR WATER, SEWERAGE AND

bottle tight

tighten. What's more, you can lay Tyton Joint pipe in rain or wet trench if need be. Result? More working days . . . fewer delays . . . time and money saved in the trench.

Want more facts about the economical joint engineers have called a most significant advance in cast iron pipe?

Write or call today

U. S. PIPE AND FOUNDRY COMPANY
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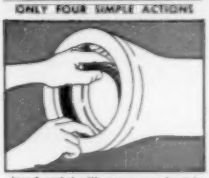
A WHOLLY INTEGRATED PRODUCER FROM MINES AND BLAST FURNACES TO FINISHED PIPE

INDUSTRIAL SERVICE

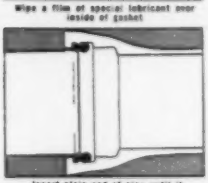
TYTON

ONLY FOUR SIMPLE ACTIONS

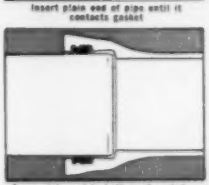


Insert gasket with groove over bead in gasket seat

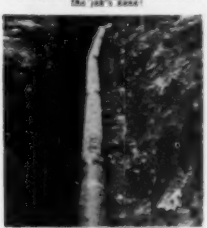
Wipe a film of special lubricant over inside of gasket



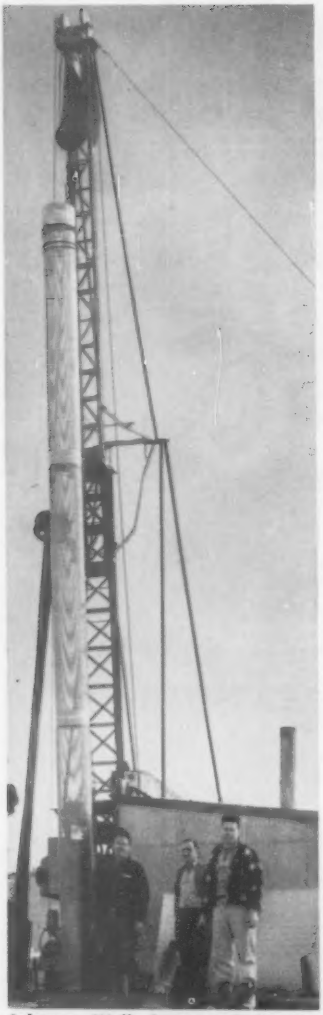
Insert plain end of pipe until it contacts gasket



Force plain end to bottom of socket . . . the job's done!



8" Tyton Joint water line for new high school in Alabama.



Johnson Well Screen of Everdur being lowered into the new 4-mgd well at Plymouth, Mich.

Big screen of EVERDUR serves new 4,000,000-gallon well in Plymouth, Mich.

In developing a new source of water to meet growing community needs, Plymouth, Mich., more than doubled the capacity of its water system with a single well capable of providing 4,032,000 gallons per day.

The new well is 110 feet deep, has an 18-inch casing, and a Johnson Everdur Well Screen 16¼" in diameter by 32', 1½" long. Edward E. Johnson, Inc., St. Paul, Minn., fabricates tough, corrosion-resistant well screens from specially shaped Everdur wire and rod by a unique automatic welding method. Johnson welded Everdur screens have proved their durability by years of service in large-capacity wells.

• **Everdur* resists corrosion.** Sewage-treatment and waterworks equipment of Everdur has been in service without replacement for 20 years and longer.

• **Everdur is tough.** Everdur also possesses high mechanical strength and resistance to wear and abrasion—so that engineers can design light-weight, wrought-metal equipment.

• **Everdur is readily fabricated.** Alloys are available for hot or cold working, welding, free machining, forging, and casting—and can be obtained in plates, sheets, rods, bars, wire, tubes, electrical conduit, and casting ingots.

• **Write for Publication E-11,** "Everdur Copper-Silicon Alloys for Sewage Treatment and Waterworks Equipment"—or for technical help in selecting the correct material for your job. Address: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont.

*Reg. U. S. Pat. Off. 57132

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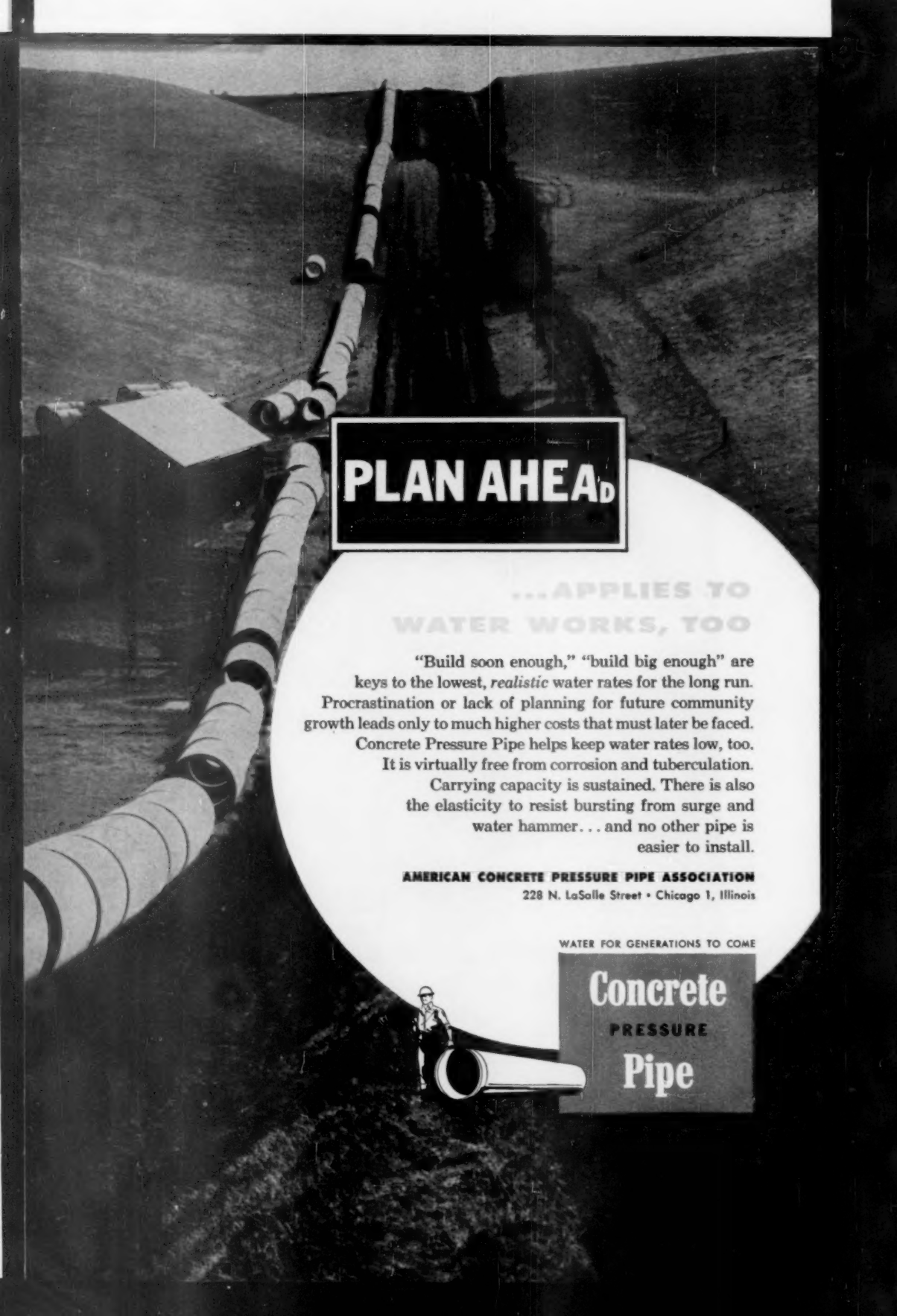
MADE BY THE AMERICAN BRASS COMPANY
STRONG • WORKABLE • WELDABLE • CORROSION-RESISTANT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...APPLIES TO
WATER WORKS, TOO
"Build soon enough," "build big enough" are keys to the lowest, *realistic* water rates for the long run. Procrastination or lack of planning for future community growth leads only to much higher costs that must later be faced. Concrete Pressure Pipe helps keep water rates low, too. It is virtually free from corrosion and tuberculation. Carrying capacity is sustained. There is also the elasticity to resist bursting from surge and water hammer... and no other pipe is easier to install.
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228 N. LaSalle Street • Chicago 1, Illinois
WATER FOR GENERATIONS TO COME
Concrete
PRESSURE
Pipe

the right

Combination...

Design, rugged construction and operating experience are combined in just the right proportions to make Nichols Herreshoff Multiple Hearth Furnaces the most efficient and cleanest of all sewage sludge heat disposal methods.

Burn sewage sludge, grit, skimmings, screenings, or dry sewage sludge in one simple, compact furnace. No offensive smoke, odor, fly ash.

Nichols Herreshoff

Multiple Hearth Dryer - Incinerators

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NEW Wedge-Lock* JOINTS
Greatest Contribution to Sanitary Engineering since Vitrified Clay Pipe
Like a Railroad Coupling ... Wedge-Lock Joints wedge in! lock tight! in one simple, easy operation
Bonded-on Wedge-Lock Joints control infiltration to strict specifications . . . insure completion of the job exactly as designed . . . reduce pumping costs . . . save installation time . . . last as long as the world's longest-lasting pipe!
Always specify Vitrified Clay Pipe, with Wedge-Lock Factory-Made Joints. Write to listed manufacturers for literature or an actual Wedge-Lock demonstration.
*Patented. Trademark Registered

Wedge-Lock CLAY PIPE

THE FACTORY-JOINTED CLAY PIPE AVAILABLE NATIONALLY FROM LOCAL MANUFACTURERS

Order Wedge-Lock from any of these Vitrified Clay Pipe Manufacturers

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The Evans Pipe Co., Uhrichsville, O.
The Logan Clay Products Company, Logan, Ohio
Pacific Clay Products, Los Angeles 54, Calif.
Pomona Terra-Cotta Company, Greensboro, N.C.
Graff-Kittanning Clay Products, Worthington, Pa.
Gladding, McBean & Co., Los Angeles 54, Calif. (*Sold under trade name, "SPEED-SEAL"*)
Clay City Pipe Company, Uhrichsville, Ohio
Oconee Clay Products Company, Milledgeville, Ga.
Pine Hall Brick & Pipe Company, Winston-Salem, N.C.
The Robinson Clay Product Company, Akron 9, Ohio
Superior Clay Corporation, Uhrichsville, Ohio
The Stillwater Clay Products Company, Cleveland 16, Ohio

Here is one of the aeration tanks in Kewanee, Illinois, using the P.F.T. Dual Aeration Equipment. Crawford, Murphy and Tilly, Consulting Engineers, Springfield, Illinois.

Note P.F.T.'s removable aeration plates which permit service without shutdown.

Existing plant capacity doubled with P.F.T. Dual Aeration System

Can increased flow and loading be handled without additional aeration tank volume? Yes—with the P.F.T. Dual Aeration System and P.F.T. Kraus Nitrification. In fact, at Kewanee, Illinois, existing aeration tanks were originally designed for 1.0 MGD flow and are now capable of handling flows up to 2.0 MGD.

This P.F.T. Aeration System includes the P.F.T. Valved-Orifice Air Distributors and Removable Plate Diffusers.

If you would like full information about P.F.T. Dual Aeration System and other P.F.T. equipment, write us today.

The aeration tanks are also arranged to use P.F.T. Kraus nitrification for "Controlled Activated Sludge" operation.

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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 30 **December 1958** **Number 12**

Contents

Sewage Works

Sewage Treatment Plant Costs in Kansas. By Gordon E. Mau 1443

Enteric Viruses and *Salmonellae* Isolation. II. Media Comparison for *Salmonellae*. By H. H. Bloom, W. N. Mack, and W. L. Mallmann 1455

Statistical Summary of Sewage Chlorination Practice in the United States. By John R. Thoman and Kenneth H. Jenkins 1461

Survival of *Salmonella Typhosa* During Anaerobic Digestion. I. Experimental Methods and High-Rate Digester Studies. By Ross E. McKinney, Harold E. Langley, and Henry D. Tomlinson 1469

Industrial Wastes

Soil Adsorption of Radioactive Wastes at Los Alamos. By C. W. Christenson, Eric B. Fowler, George L. Johnson, Elgin H. Rex, and Felix A. Virgil ... 1478

Predacious Fungus Behavior in Activated Sludge Systems. By Wm. Bridge Cooke and F. J. Ludzack 1490

Stream Pollution

Aeration of Stream Flow at Power Turbines. By R. H. Scott and T. F. Wisniewski; and B. F. Lueck and A. J. Wiley 1496

The Operator's Corner

Operator Ingenuity at the Tacoma, Washington, Sewage Treatment Plant. By Lyman Ketcham 1506

Work Area Protection. By Gordon L. Smith 1518

Tips and Quips 1522

News and Notes 1524

Federation Affairs

William D. Hatfield New President 1525

Mark D. Hollis Elected Vice-President 1526

Detroit Hosts Thirty-First Annual Meeting 1527

Detroit Board of Control Meetings 1530

Table of Contents for Volume 30 ii

Author Index ix

Subject Index xiv

Geographical Index xxvi

Proceedings of Member Associations

Michigan Sewage and Industrial Wastes Association 504a

Pennsylvania Sewage and Industrial Wastes Association 508a

Ralph E. Fuhrman, *Editor*, 4435 Wisconsin Ave., N.W., Washington 16, D. C.
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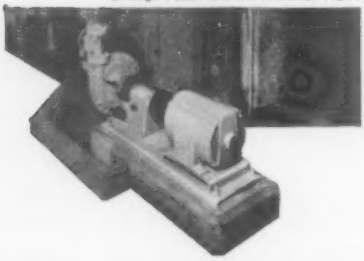
FROM DORR-OLIVER

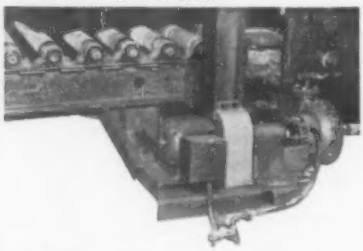
for tough acid and trade waste pumping problems

Six Olivites, at The Creamery Package Mfg. Company's Arlington Heights, Illinois plant, handle acid and alkali solutions.

Hydrofluosilicic acid transfer service at Chicago's South District Filtration Plant.



Handling pickle liquor on scrubbing and drying line at Gary Sheet and Tin Mill, this Olivite has given excellent service for over three years.



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Sewage Works

SEWAGE TREATMENT PLANT COSTS IN KANSAS

By Gordon E. Mau

Sanitary Engineer, Ediger and Company, Wichita, Kans.

All sanitary engineers in water pollution control activities are asked the question—"How much will it cost our community to construct a sewage treatment plant?" When the officials are given an estimated cost they usually reply that costs have increased so much that the community cannot afford to undertake the project and, with a great deal of remorse, wish that they had proceeded with construction of the plant several years before when costs were lower. The cost of a sewage treatment plant is also frequently considered to be an insurmountable barrier by many officials because it is often the largest construction project in terms of cost ever considered by the community.

Plant costs for the period 1922–56 were obtained so that the cost of new plants could be analyzed for trends and to have general information for an answer to the above question. Several sources, including city records, and consulting engineers' and Kansas State Board of Health files, were investigated in gathering these data.

From 1922 to 1956 there were over 350 sewage treatment plant projects in Kansas of which about 55 per cent were constructed after World War II. This progress is illustrated in Figure 1. Of the $66,000,000 in bonds issued

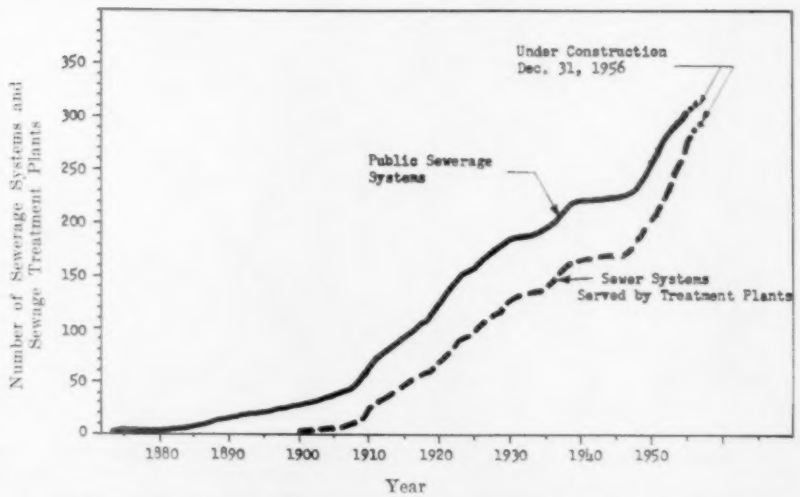

FIGURE 1.—Growth of Kansas sewerage facilities from 1873 to 1956.

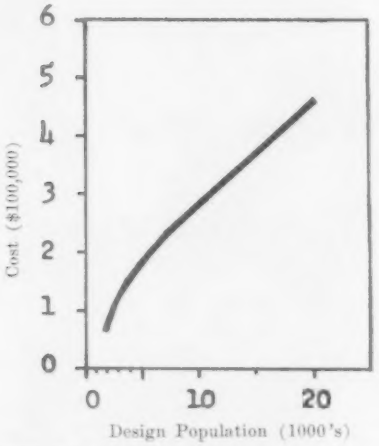

FIGURE 2.—Cost of secondary treatment plants in Kansas, 1922–29.*

(adjusted to Engineering News-Record Construction Cost Index of 700) for sewerage works from 1946–56 inclusive, approximately 42 per cent was for treatment works.

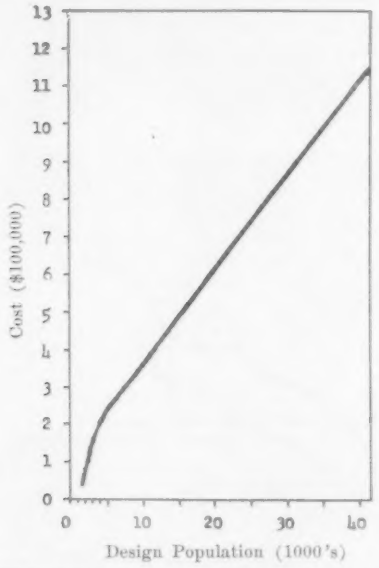

FIGURE 3.—Cost of secondary treatment plants in Kansas, 1930–39.*

* Costs adjusted to ENR Construction Cost Index = 700; 1913 = 100.

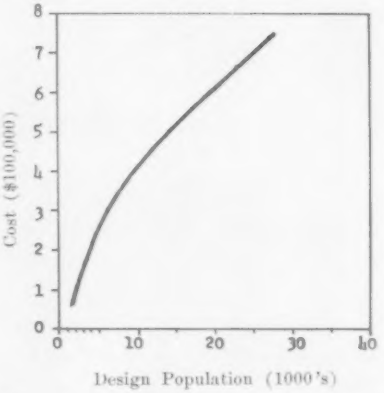

FIGURE 4.—Cost of secondary treatment plants in Kansas, 1940–49.*

The total cost—including construction, engineering, legal, land, etc.—for new plant projects (no plant enlargement data included) has been adjusted to the ENR Construction Cost Index of 700. These adjusted costs are shown for the periods 1922–29, 1930–39, 1940–49, and 1950–56 in Figures 2 through 5; the section of these curves for plants with a design population of less than

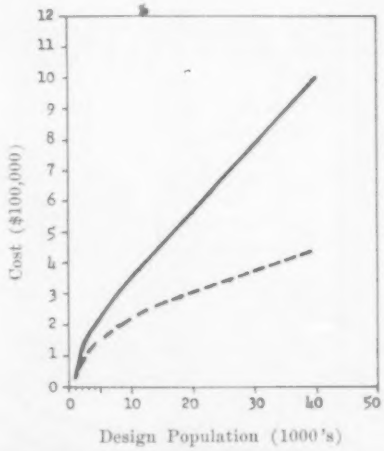

FIGURE 5.—Sewage treatment plant costs in Kansas, 1950–56. Solid curve represents secondary plants. Dashed curve represents primary plants.*

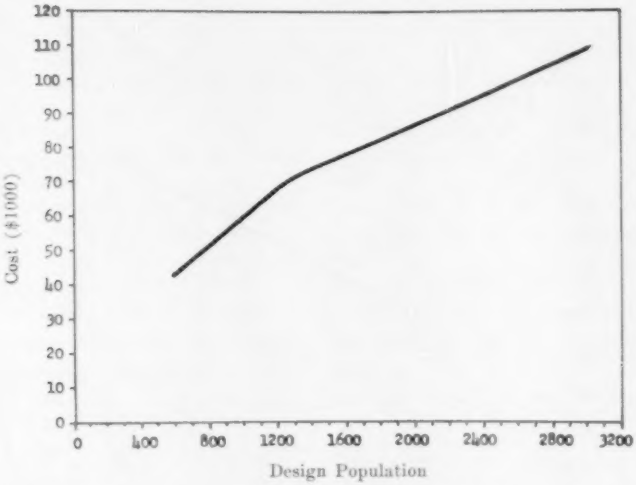

FIGURE 6.—Cost of secondary treatment plants in Kansas for design populations of less than 3,000, 1922–29.*

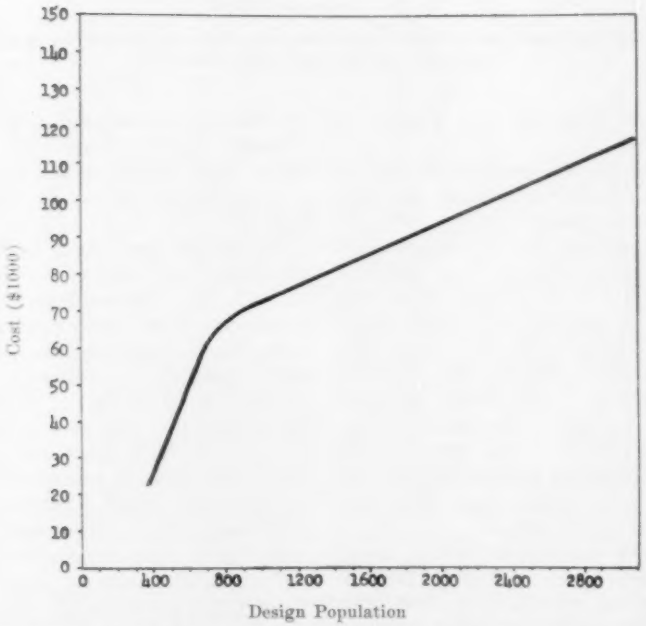

FIGURE 7.—Cost of secondary treatment plants in Kansas for design populations of less than 3,000, 1930–39.*

* Costs adjusted to ENR Construction Cost Index = 700; 1913 = 100.

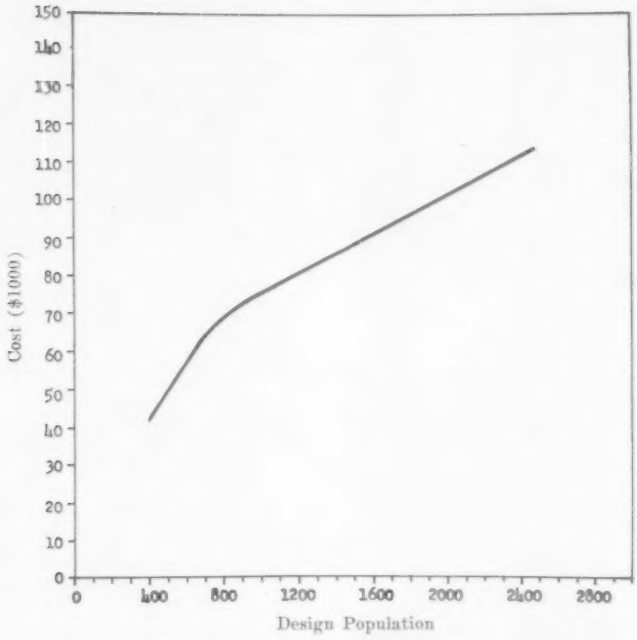

FIGURE 8.—Cost of secondary treatment plants in Kansas for design populations of less than 3,000, 1940–49.*

3,000 are presented in Figures 6 through 9.

Most of the design criteria for the period 1922–39 were much different from current design policies. For example: some of the Imhoff tanks of that era were designed for a digestion capacity of 1 to 2 cu ft/cap; flow rates of 50 to 75 gpd/cap were often used; trickling filter capacity was often based on 250 to 350 lb BOD/acre-ft/day; and final settling basins were not provided in most of the earliest trickling filter plants. Thus, costs over the 35 years based on different design criteria are not a suitable basis for evaluating changes in costs.

A goodly number of sewage treatment plants constructed from 1922–39 were still in operation in 1956. In 1956, the capacity of each of these plants was re-evaluated, based on the current design policy. These plant costs, based on the revised design population, are presented in Figures 10 and 11.

All of the cost curves in Figures 2 through 11 are summarized in Figures 12 and 13. These curves show that treatment plant costs have increased each decade based on the initial design population. However, when plants are all evaluated on the same design policy, it is apparent that plants constructed from 1922 to 1939 cost more per unit of volume than have plants which were constructed from 1940 to 1956 (mostly contracted for after 1945). The construction cost index closely parallels wage curves. Thus, today a smaller portion of earnings are needed per unit of volume to finance the construction of sewage treatment plants. This means that the

* Costs adjusted to ENR Construction Cost Index = 700; 1913 = 100.

over-all problem mentioned in the initial paragraph is not actually true. In fact, if it were true, it is unlikely that many of the nearly 100 Kansas communities with populations less than 1,000 which have constructed sewer systems and treatment plants since 1945 could have done so.

It is also important to consider types of treatment processes when dealing with costs. The types of treatment facilities constructed each decade in Kansas since 1900 are listed in Table I. These data show that modern treatment processes became prominent after 1921. This tabulation also shows that: (a) the separate sludge digestion process is now being used for a greater percentage of plants even though many of the plants are for populations of less than 2,000; (b) two-stage sludge digestion is being provided at a greatly accelerated rate (1); (c) trickling filters are used for secondary treatment in most cases; and (d) oxidation ponds (preceded by at least primary treatment) are the second most common form of secondary treatment.

The cost data indicate that an Imhoff tank is often an economical treatment process for a small community, but this cannot always be assumed to

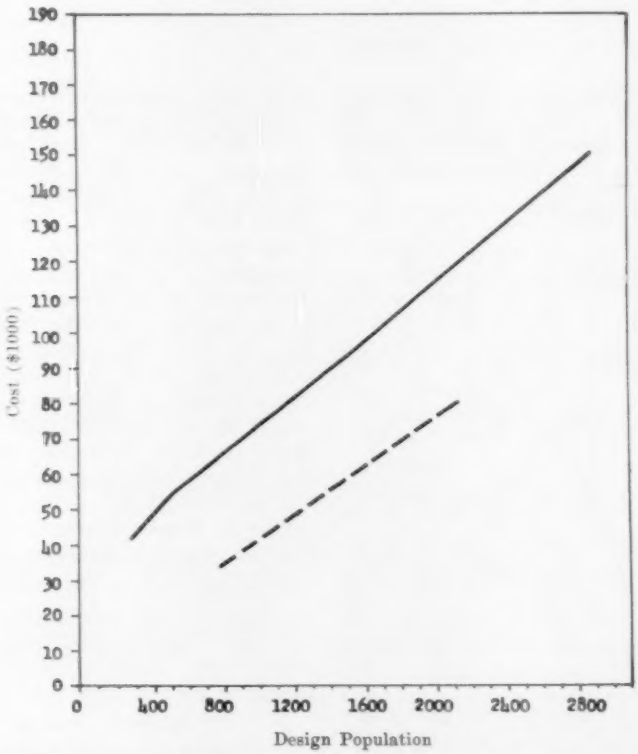

FIGURE 9.—Cost of sewage treatment plants in Kansas for design populations of less than 3,000, 1950–56.* Solid curve represents secondary plants. Dashed curve represents primary plants.

* Costs adjusted to ENR Construction Cost Index = 700; 1913 = 100.

TABLE I.—Types of Treatment Units Constructed in Kansas from 1900 to 1956

Type of Treatment Unit	Number of Units Constructed					
	1900–10	1911–20	1921–30	1931–40	1941–50	1951–56
Primary treatment:						
Septic tank	25	39	1	—	—	—
Imhoff tank	—	14	63	51	42	81
Clarifier	—	—	8	22	16	48
Sludge digestion:						
Heated	—	—	5	16	11	26
Unheated	—	—	5	9	7	22
2-stage	—	—	2	5	7	28
Secondary treatment:						
Contact beds	4	20	2	—	—	—
Sand filter	1	11	34	13	—	3
Trickling filter	—	3	19	46	53	91
Activated sludge	—	—	5	6	1	1
Contact aeration	—	—	—	—	—	3
Oxidation ponds*	—	1	1	9	8	17
Raw sewage lagoons	—	—	—	—	—	2

* Preceded by at least primary treatment.

be true. Analysis of the data suggests that for nearly 50 per cent of the secondary treatment plants for populations of less than 3,000, it might have been more economical to have used primary settling and digesters rather than Imhoff tanks. The Imhoff tank has been a practical and economical process for many small communities. However, changes in sewage loads, such as the addition of substantial quantities of garbage, are causing the Imhoff tank to be inflexible and inadequate for an increasing number of these modern communities.

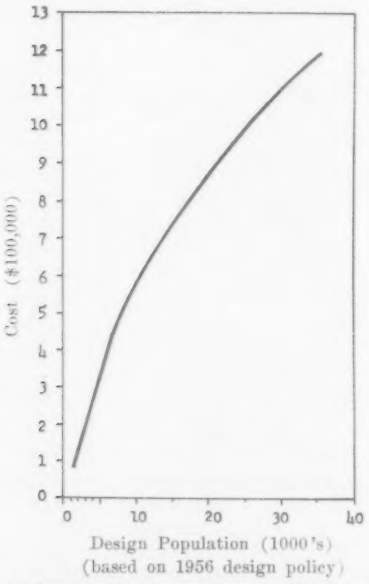

FIGURE 10.—Cost of secondary treatment plants in Kansas built during 1922–39 and still in operation in 1956.*

* Costs adjusted to ENR Construction Cost Index = 700; 1913 = 100.

The decision on which type of primary treatment to provide can no longer be made on the basis that Imhoff tanks are a simple process and therefore receive the best operation. Even the small separate sludge digestion plants in Kansas are generally operated as well or better than are plants with Imhoff tanks. The quality of operation, using the same personnel, has generally been improved where a separate sludge digestion plant has replaced an Imhoff tank.

Velz (2) analyzed construction cost data from the period 1920–48 for about 500 sewage treatment plants. The results of his statistical analysis are reproduced in Figure 14. These curves are for construction costs only and do not include land, engineering, legal,

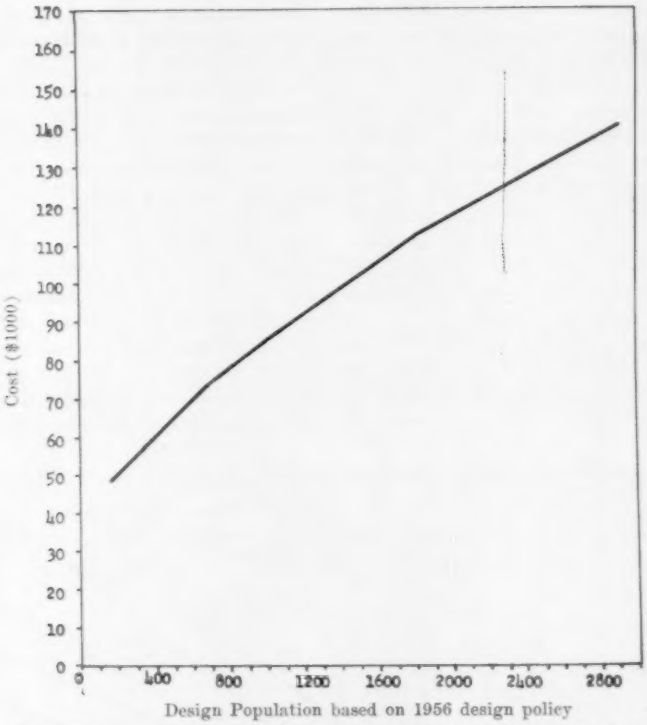

FIGURE 11.—Cost of secondary treatment plants in Kansas for design populations of less than 3,000. Plants were built during 1922–39 and still in operation in 1956.*

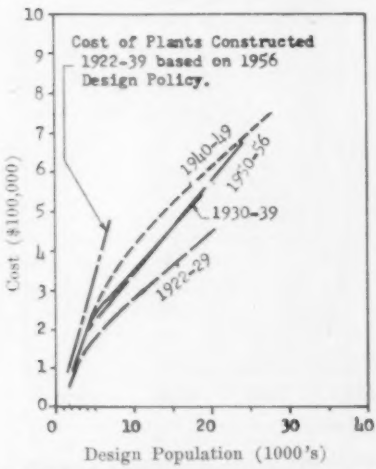

FIGURE 12.—Summary of cost of secondary treatment plants in Kansas, 1922–56.*

* Costs adjusted to ENR Construction Cost Index = 700; 1913 = 100.

etc.; they are also for 100 per cent plant efficiency.†

Total costs for secondary treatment plants in 1950–56 (Figs. 5 and 9), and some costs for secondary plants completed during 1957–58 in Kansas, have been recalculated on the basis of cost per mgd of capacity on the assumption of a 100 gpd/cap sewage flow. These data are plotted in Figure 15 along with Velz's construction cost curves for 100 per cent efficient plants with a capacity less than 10 mgd, adjusted to an ENR

† The most probable construction cost for a conventional trickling filter plant removing 85 per cent of the BOD, as determined by these data and based on the 1926 Index = 100, is obtained by multiplying:

$$\frac{Unit\ Cost}{mgd} \times Plant\ size\ (mgd) \times 0.85 \times \frac{ENR\ Construction\ Cost\ Index}{1926\ Index}$$

construction cost index of 700; also, the range of Velz's curves has been shown for 70 and 85 per cent plant efficiencies.

In comparing costs in Kansas with Velz's curves, it should be noted that his curves are for construction costs only whereas the Kansas data are the total plant cost. Also, Velz analyzed costs for plants ranging in size from about 0.1 to 700 mgd, whereas the Kansas costs are for plants ranging in size from 0.03 to 4.0 mgd.

The costs analyzed by Velz tend to be high, relative to the curves, for plants with a capacity of less than 1.0 mgd. On the other hand, the costs of Kansas plants (1950–56) generally fall within the range established by Velz's curves for a 70 per cent plant efficiency for design flows of 0.1 to 4.0 mgd. Kansas costs tend to be high in the extrapolated range of Velz's curves for 70 per cent efficiency for design flows smaller than 0.1 mgd.

From the average cost curves in Figure 12, based on the current design policy, a 6,000 population plant constructed during the period 1950–56 cost 35 per cent less, based on the same dollar value, than did a comparable plant constructed during the period 1922–39. Velz's curves for the construction costs of 100 per cent efficient

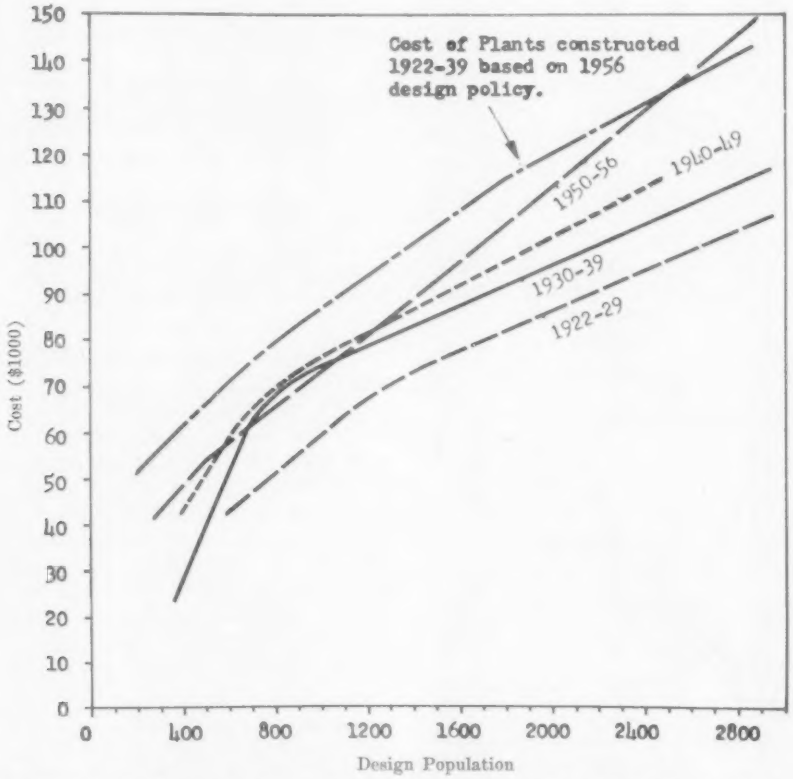

FIGURE 13.—Summary of cost of secondary treatment plants in Kansas for design populations of less than 3,000, 1922–56.*

* Costs adjusted to ENR Construction Cost Index = 700; 1913 = 100.

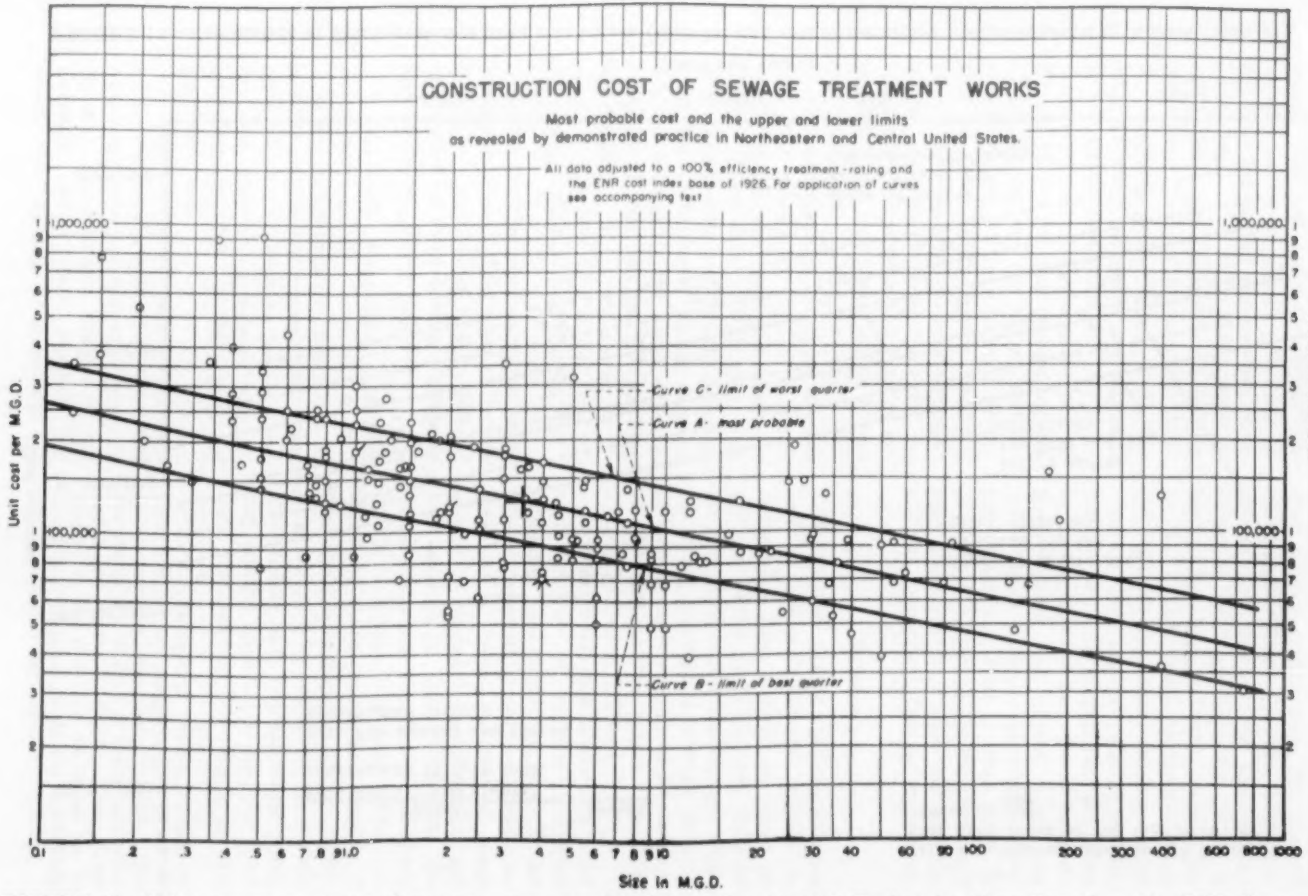
CONSTRUCTION COST OF SEWAGE TREATMENT WORKS
Most probable cost and the upper and lower limits as revealed by demonstrated practice in Northeastern and Central United States.
All data adjusted to a 100% efficiency treatment - rating and the ENR cost index base of 1926. For application of curves see accompanying text
Curve C - limit of worst quarter
Curve A - most probable
Curve B - limit of best quarter
Unit cost per M.G.D
Size in M.G.D.
1,000,000
100,000

FIGURE 14.—Velz's sewage treatment plant cost curves reproduced from Oct. 14, 1948, Engineering News-Record, p. 84. ENR Construction Cost Index in 1926 was approximately 205 based on 1913 = 100.

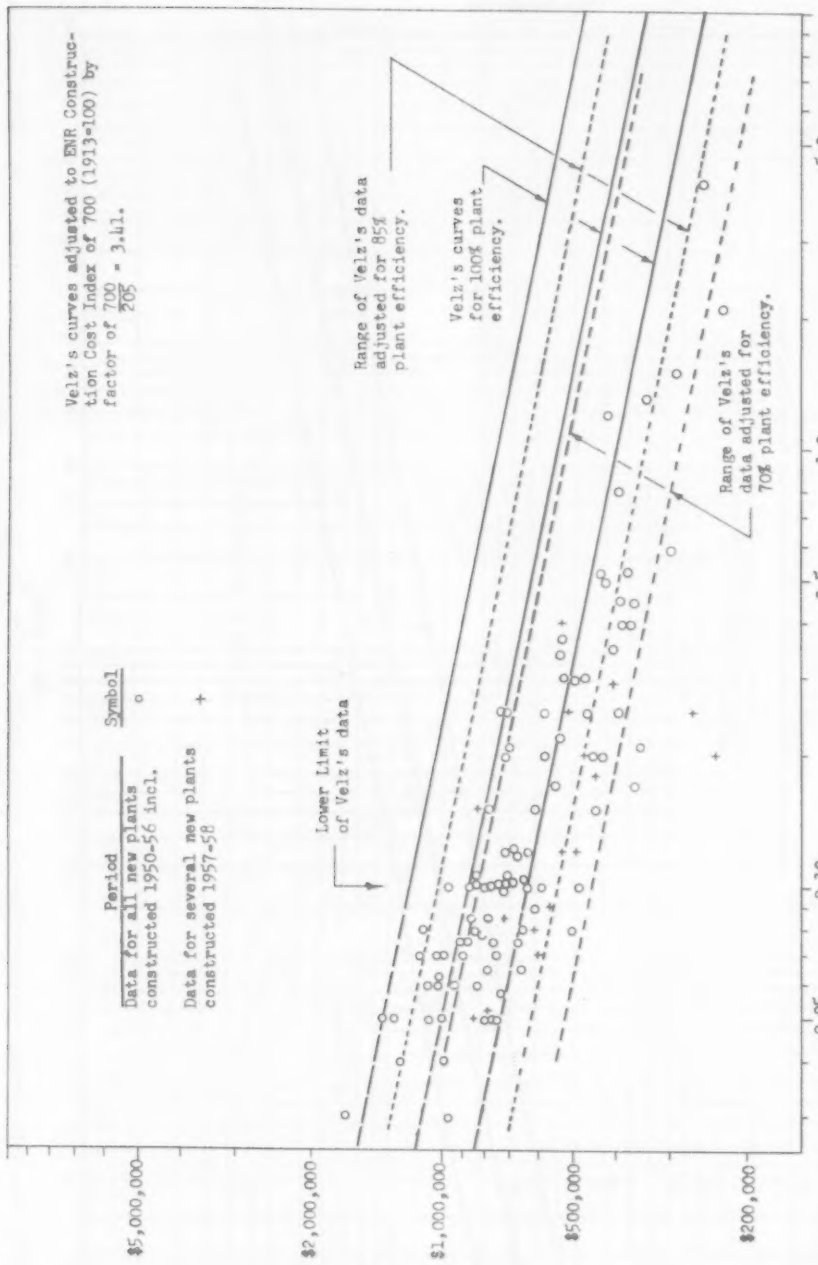

FIGURE 15.—Comparison of Velz's treatment plant cost curves (1920–48) and cost of secondary treatment plants in Kansas (1950–58).

plants are probably quite close to the actual total cost for conventional secondary treatment plants (allowing 15 per cent for cost of engineering, land, legal, etc.). If this assumption is valid, there has been about a 30 per cent reduction in plant costs for 1950–56 compared with Velz's costs for 1920–48 when all costs are adjusted to a common base value.

Some of the 1957–58 cost data in Figure 15 are for raw sewage lagoons of which two are the lowest cost facilities in the 0.2 to 0.25 mgd group. One of these latter lagoon facilities cannot be considered as representative of an adequate facility, however, because after more than one year of operation it has not been possible to use more than one of the three cells due to excessive seepage. If these lagoons had been adequately sealed to minimize seepage, the unit cost would be higher. These data indicate that, with some lagoon costs being in the range of costs for conventional plants, lagoons are not necessarily the lowest cost facility for all locations just because they are simple.

Cost Saving Innovations

Credit for the relative reduction of sewage treatment plant costs in Kansas is due to a number of reasons beyond more efficient construction procedures and facilities. These include:

1. Increased competition between contractors;

2. Encouragement by the State to use the simplest of conventional processes which are adequate for the project and, thereby, avoiding "closed" specifications for specific patented processes; and

3. Elimination of equipment wherever possible unless there is a decided advantage (cost- or operation-wise) in its use. For example: the use of grit channels rather than aerated grit units; the shaping of digesters (1) and sludge circulation to minimize dead spaces rather than the use of mechanical mixers (proven most economical by competitive bids); construction of large capacity (6 to 8 hr) sludge hoppers with steep sides (1.75:1) and small bottoms (about 1 ft by 1 ft) in primary settling basins —rather than separate sludge concentrators—with direct pumpage of sludge to the digesters;* and use of concrete flow division and control structures rather than piping and valves whenever practical. Most of these items, if properly incorporated in the plans, not only tend to reduce costs but also facilitate economical future expansion.

Summary

It has been shown that the relative cost of sewage treatment plants in Kansas has been reduced by about 35 per cent when costs between 1922–40 are compared with costs between 1950–56. Also, plant costs between 1950–56 in Kansas have been about 70 per cent of the cost of the plants that Velz analyzed between 1920–48.

It is a difficult task to evaluate plant costs because of varying treatment processes, local conditions, etc. To arrive at reasonably representative conclusions, a large number of costs should be analyzed and there has not been enough of this. With the detailed cost data required for Federal grants in sewage treatment plant construction, there should be a wealth of reasonably accurate cost data. Therefore, it should be one of the main goals of the state and Federal water pollution control agencies to analyze these data and publish the results at fre-

* D. B. Kissinger of Topeka, Kansas, reports that the raw sludge pumped to the digesters averages better than 6% solids. This raw sludge is a mixture of raw sewage solids and waste activated sludge. The sludge hoppers in the center of the basins are 13 and 2 ft in diameter at the top and bottom, respectively, and they are 9.25 ft deep.

quent intervals. Such analyses should be on at least a state or regional basis as well as a national basis.

Acknowledgments

Most of the data in this paper were obtained by the author while Chief of Water Pollution Control, Kansas State Board of Health. Thanks are due Carl Hodgkinson, his successor in that position, for supplying cost data for 1957–58.

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1. Mau, G. E., "Applying Recent Research to Design of Separate Sludge Digesters." THIS JOURNAL, **28**, 10, 1199 (Oct. 1956).
2. Velz, C. J., "How Much Should Sewage Treatment Cost?" *Eng. News-Rec.*, **141**, 16, 84 (1948).

MEETINGS OF INTEREST

1958

Dec. 12–13 **Fifth Annual Wastes Engineering Conference,** The University of Minnesota, Minneapolis, Minn. Director, Center for Continuation Study, University of Minnesota, Minneapolis 14, Minn.

1959

Jan. 19–23 **American Institute of Electrical Engineers,** New York, N. Y.

Jan. 26–30 **Water and Sewage Plant Operators' School,** University of Colorado, Denver Extension Center. Write to: Water and Sewage Plant Operators' School, Room 305, 1165 Broadway, Boulder, Colo.

Feb. 12–13 **Florida Water Resources Conference,** University of Florida, Gainesville, Fla. Write to: Department of Water Resources, The Capitol, Tallahassee, Fla., or the Public Service Training Center, 28 Dining Hall, Florida State University, Tallahassee, Fla.

Feb. 15–19 **American Institute of Mining, Metallurgical, and Petroleum Engineers,** San Francisco, Calif.

Mar. 16–20 **National Association of Corrosion Engineers,** Sherman Hotel, Chicago, Ill.

Apr. 2–3 **Eighth Southern Municipal and Industrial Waste Conference,** University of North Carolina, Chapel Hill, N. C. Dr. Daniel A. Okun, Dept. of Sanitary Engineering, School of Public Health, University of North Carolina, Chapel Hill, N. C.

Apr. 5–10 **American Chemical Society,** 135th National Meeting, Boston, Mass. R. M. Warren, American Chemical Society, 1155 16th St., N. W., Washington 6, D. C.

Apr. 5–10 **Fifth Nuclear Engineering and Science Conference,** Public Auditorium, Cleveland, Ohio. T. A. Marshall, Jr. (Congress Manager) or L. K. Wheelock (Asst. Manager), c/o Engineers Joint Council, 29 West 39th Street, New York 18, N. Y.

Dec. 8–10 **American Nuclear Society,** Sheraton-Cadillac Hotel, Detroit, Mich. Octave J. DuTemple, Executive Secretary, American Nuclear Society, 86 East Randolph St., Chicago 1, Ill.

ENTERIC VIRUSES AND *SALMONELLAE* ISOLATION

II. MEDIA COMPARISON FOR *SALMONELLAE*

By H. H. Bloom, W. N. Mack, and W. L. Mallmann

Department of Microbiology and Public Health, Michigan State University, East Lansing, Mich.

An earlier report (1) discussed the isolation of viruses from sewage. Concurrently, attempts were made to isolate and to determine the incidence of *Salmonellae*.

Stokes and Osborne (2) described a selenite brilliant green (SBG) enrichment medium for the isolation of *Salmonella*. This liquid primary enrichment medium was reported to be more effective than the more commonly used selenite F broth in that growth of strains of *Escherichia* and *Proteus* were inhibited to a greater extent. In addition to preventing excessive growth of non-*Salmonella* organisms, SBG medium supported abundant growth of *Salmonella* from very small inocula. Thirteen smooth stock strains of *Salmonella* were tested by Kenner, Rockwood, and Kabler (3) utilizing SBG medium in conjunction with the membrane filter. Recovery rates of 40 to 60 per cent were obtained with the SBG medium as compared to 10 per cent or less using various formulations of SS medium (*Salmonella-Shigella*) with the membrane filter procedures.

The presence of *Salmonella* in irrigation waters was reported by Dunlop, Twedt, and Wang in 1951 (4). Using tetrathionate enrichment broth followed by streaking on bismuth sulfite agar plates, 23 of 113 samples were positive for *Salmonella* comprising 13 species. Four of 21 1-ml samples were found to be positive, 5 of 12 10-ml samples were positive for *Salmonella*, and 14 of 66 100-ml samples were also positive for this enteric pathogen. In a later paper (5) Dunlop *et al.* compared recoveries of *Salmonella* from naturally-contaminated irrigation water with Difco tetrathionate broth and with Galton's modification (6). Galton's modification consisted of the addition of sodium-sulfathiazole to Kauffmann's brilliant-green tetrathionate broth. This modified medium resulted in obtaining higher recovery rates than did the regular tetrathionate broth. In this study, the volume of irrigation water sampled ranged from 333 to 3,000 ml and the material was concentrated ten-fold using a Foerst continuous centrifuge.

Using the gauze sampling procedure of Moore (7), Greenberg, Wickenden, and Lee (8) traced a typhoid carrier by sampling along various points of a small city's sewerage system.

It is the purpose of this paper to report on the efficacy of SBG medium in the isolation of *Salmonella* from sewage and of the occurrence of *Salmonella* in the various stages of treatment in an activated sludge treatment plant.

Experimental Method

Sampling

Beginning in October 1956, two sewage specimens were collected each week from Lansing (population 92,000 in 1950) and from adjoining East Lansing, Mich. (population 40,000). Samples were collected from a pumping station in Lansing and from the main plant in East Lansing. Two types of specimens were obtained: gauze pad and raw sludge. From July to De-

cember 1957, gauze pad and raw sludge samples were collected only from the East Lansing plant on an unscheduled basis. Gauze pad specimens were obtained from six sources: (a) raw sewage, (b) effluent from the primary settling tanks, (c) aeration tanks, (d) final settling tanks, (e) return activated sludge line, and (f) final effluent (unchlorinated). The raw sludge samples were collected from the pipe line when sludge was being pumped to the digesters.

Methods of Sampling

The gauze pads, 4 in. by 4 in. square, were placed directly into the flow and remained in contact at the various sampling stations from 24 to 72 hours. Approximately 150 ml of raw sludge was collected from an outlet on a sludge pump and represented a 24-hr sample, as the raw sludge was held in a holding tank and pumped to the digesters once daily. Specimens were processed in the laboratory within one hour of collection, with the exception of the sludge sample, which was held at 4°C in the treatment plant for as long as six hours following collection.

Laboratory Procedure

From October 1956 through June 1957 the samples were incubated in Difco tetrathionate broth and in the period July to December 1957, the samples were enriched in SBG medium. The absorbed liquid in the gauze pads was extracted by placing the pad in the barrel of a 100-ml syringe and forcing the liquid through by applying pressure with the plunger. The amount of sample volume ranged from 20 to 45 ml. Since a major portion of this specimen was used for the isolation of viruses, described earlier (1), a 1-ml sample was taken from the thoroughly mixed specimen and transferred to a flask containing 150 ml of SBG medium. (Later work has shown 25 ml of SBG medium to be sufficient for 1 ml of inoculum.) Approximately 1 ml of the raw sludge was also used an an inoculum for 150 ml of SBG medium. The inoculated flasks were incubated for 18 to 24 hr at 37°C. One large loopful of material was then streaked onto a Difco bismuth sulfite agar plate which was incubated at 37°C for 24 to 28 hr. Typical *Salmonella*-like colonies were picked and inoculated into triple sugar iron agar tubes. At least four suspicious colonies were picked from each plate when possible. Transfers into tubes of Stuart's urea broth, Simmon's citrate agar, nutrient agar and one per cent solutions of lactose, sucrose, salicin, and mannite were made from tubes of triple sugar iron agar showing *Salmonella*-like reactions. Final serological typing was performed by the *Salmonella* Typing Station of the Michigan Department of Health Laboratories.

Results

During the first half of the study, using tetrathionate broth as the enrichment medium, 32 of 142 gauze pad and sludge samples were positive for *Salmonella* (Table I). From these 32 positive specimens, 49 *Salmonellae* representing 14 species were obtained. It should be noted that from approximately the same number of gauze pad samples taken in the two cities, there was a marked difference in the recovery rates. In Lansing, 6 of of the 59 specimens were positive and in East Lansing, 17 of 56 specimens were positive for *Salmonella*. Since sludge samples were taken only from East Lansing, no comparison can be made with Lansing. Nine of 27 raw sludge samples were positive (33 per cent) and the recovery was comparable to that from the gauze pad samples in East Lansing (30 per cent). However, the 9 positive sludge samples yielded 16 *Salmonellae* that included 9 species, whereas the 17 positive gauze pad samples yielded 23 *Salmonellae* representing 6 species (Table II).

TABLE I.—Comparison of Tetrathionate Broth and Selenite Brilliant Green Media in the Isolation of *Salmonella* from Sewage

Sample	Tetrathionate Broth*			Selenite Brilliant Green Medium†		
	No. Positive Isolations	Total No. Specimens Tested	% Positive	No. Positive Isolations	Total No. Specimens Tested	% Positive
Lansing:						
Gauze pads	6	59	12	—	—	—
Sludge	—	—	—	—	—	—
E. Lansing:						
Gauze pads	17	56	30	43	71	60
Sludge	9	27	33	19	21	90
Totals:						
Gauze pads	32	142	23	62	92	67
Sludge	9	27	33	19	21	90

* Sampling period, Oct. 1956 to June 1957.
† Sampling period, July to Dec. 1957.

The number of *Salmonella* isolated in the July to December period is also shown in Table I. Fewer samples were taken during this phase of the study (92) and a greater number of isolations were made; 62 positive samples yielded 83 *Salmonellae* representing 17 species (Table II). A new

TABLE II.—Isolation of *Salmonella* from Gauze Pads and Raw Sludge According to Location

Species	Tetrathionate Broth			Selenite Brilliant Green	
	Lansing	East Lansing		East Lansing	
	Pad	Pad	Sludge	Pad	Sludge
S. muenchen	—	10	5	2	4
S. montevideo	1	6	2	3	3
S. derby	—	2	1	5	5
S. anatum	—	2	1	9	5
S. tennessee	2	3	—	—	1
S. typhimurium	3	—	2	—	2
S. worthington	—	—	1	—	—
S. infantis	—	—	2	1	2
S. thompson	—	—	1	—	—
S. reading	—	—	1	—	—
S. paratyphi B	—	—	—	8	2
S. heidelberg	—	—	—	3	1
S. san diego	—	—	—	18	2
S. lansing	—	—	—	—	1
S. typhi	—	—	—	—	1
S. kentucky	—	—	—	1	—
S. berta	1	—	—	1	—
S. bareilly	—	—	—	1	—
S. give	—	—	—	1	—
S. california	—	—	—	1	—
S. cerro	1	—	—	—	—
S. cubana	2	—	—	—	—
S. blockley	—	1	—	—	—
Totals (133)	10	24	16	54	29

Salmonella species was isolated from a sludge sample during this period. It has been named *S. lansing* and its antigenic characteristics are expected to be published. Of the 21 sludge samples tested, 19 yielded 20 *Salmonellae* which included 12 different species.

The gauze pad samples were positive on 43 of 71 occasions and included 54 *Salmonellae* representing 13 species. Eight species were common findings in both types of samples, whereas the pad samples were the only samples positive for *S. berta, S. bareilly, S. kentucky, S. give,* and *S. california.* Only the sludge samples were positive for *S. typhi, S. lansing, S. tennessee,* and *S. typhimurium.* An attempt was made to see if sampling at different plant locations had any effect on recovery of *Salmonella.* Although the number of samples is relatively small at some of the sampling points (Table III), *Salmonella* was recovered at every point in the treatment system tested.

Emphasis was placed on the sampling of the final unchlorinated effluent, since this material was discharged into the Red Cedar River which flows by the plant. A high recovery rate was obtained from this type of sample (22 of 35) indicating that although the sludge is removed at the early stage of treatment, the supernatant contains considerable numbers of *Salmonella* as it passes through the plant and even in the effluent which is discharged into the river.

Difficulties were encountered in the first phase of the study, using tetrathionate broth, in that *Proteus* was frequently encountered in such large numbers that discrete *Salmonella*-like colonies were not always easily observed. In addition to *Proteus* overgrowth on the bismuth sulfite agar plates, paracolons, simulating *Salmonella* in the triple sugar iron agar tubes, were found to be prevalent. With the change to SBG enrichment medium, little difficulty was experienced with these groups of organisms. In addition to inhibiting undesired organisms SBG medium seemed to enhance the growth of *Salmonella,* since in a large number of samples a rela-

TABLE III.—Isolation of *Salmonella* from Gauze Pads Located at Various Points in a Treatment Plant

Sampling Location	No. Positive Samples	Total No. Tested	Species
Influent	3	8	*S. san diego* (2), *S. derby*
Primary tank effluent	6	7	*S. san diego* (2), *S. paratyphi B* (2), *S. anatum* (2), *S. muenchen, S. berta, S. kentucky*
Activated sludge tank	1	6	*S. san diego*
Final settling tank	3	6	*S. san diego* (2), *S. derby, S. muenchen*
Activated sludge return	8	9	*S. san diego* (2), *S. paratyphi B* (2), *S. anatum* (3), *S. montevideo, S. give, S. california*
Final, unchlorinated effluent	22	35	*S. san diego* (9), *S. paratyphi B* (4), *S. anatum* (4), *S. heidelberg* (3), *S. montevideo* (2), *S. derby* (3), *S. bareilly, S. infantis*
Totals	43	71	54 *Salmonella* isolated

tively pure culture of *Salmonella*-like colonies were observed on the plate, and were subsequently confirmed as *Salmonella*. With the majority of samples, typical colonies were observed on the bismuth sulfite agar plates after only 24 hr of incubation.

Discussion

A marked increase in the recovery of *Salmonella* from sewage was observed when the enrichment medium was changed from tetrathionate broth to the relatively new medium of Stokes and Osborne (2). A comparison between the two time periods showed that the number of recoveries of *Salmonella* from gauze pad samples increased in East Lansing from 30 per cent (17 of 56) to 60 per cent (43 of 71) when SBG medium was used. Even greater similarities in results were obtained when the number of recoveries from sludge are compared: 33 per cent (9 of 27) when tetrathionate broth was used to 90 per cent when SBG medium was employed.

The seasonal distribution of enteric infections must be considered in the comparisons made in this study. It is generally accepted (9) that cases of salmonellosis occur throughout the year but are at a minimum during the winter and spring months, rising to a peak in the late summer and early fall. It is difficult to say whether this seasonal variation influenced the findings reported in this work. The qualitative nature of the experimental procedure does not allow such comparisons to be made, since the number of positive samples indicated only that *Salmonellae* were present in the sewage, and does not reflect on their over-all concentration.

It was not practical to run parallel studies using the two enrichment media. By using a variety of differential agar media, such as brilliant green bile agar, SS agar, and Hajna's brom cresol purple-desoxycholate citrate lactose sucrose agar (BCP–DCLS) (10), the number of isolations might have been increased (11).

The results obtained indicated that the raw sludge specimens were an excellent source of material for the isolation of *Salmonella*, and higher recovery rates were obtained from this source than from gauze pad samples. The high recovery rate from the final effluent showed that the gauze pad method of sampling serves its purpose well in monitoring supernatants.

In comparing the recovery rates from the pad samples taken in East Lansing and Lansing during the first part of the study, the fact that Lansing is a highly industrialized community while East Lansing is largely a residential area should be taken into consideration. Large amounts of industrial wastes, deposited in the sewage system, may have contributed to the lower recovery of *Salmonella* by the gauze pad method of sampling.

Whether the *Salmonella* isolated originated from human or animal sources cannot be stated. The results of this study serve to strengthen the conclusion of Greenberg *et al.* (8) that "typhoid, and presumably other enteric infections, should be recognized as a definite occupational hazard for treatment plant operators." In addition to the direct hazard to the plant operators, there exists a potential health hazard to the community. Even if the water is not directly used for drinking or swimming purposes, the return of unchlorinated final effluent containing pathogens to a river flowing through a community cannot be condoned. It is reasonable to suspect a contaminated water source as one of the many links in the transmission of disease. Proper chlorination of final sewage treatment plant effluents would serve as good preventive medicine.

Conclusions

The study reported herein led to the following conclusions:

1. Selenite brilliant green enrichment medium was superior to tetrathionate broth in the isolation of *Salmonella* from sewage. A comparison between the two media showed that the recovery of *Salmonella* from gauze pad samples increased in East Lansing from 30 per cent (17 of 56) to 60 per cent (43 of 71) when SBG medium was used.

2. Raw sludge as well as gauze pad samples provided a good source of material for the isolation of *Salmonellae*.

3. *Salmonellae* were found in all stages of sewage plant treatment tested, including final effluent.

Acknowledgment

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AVAILABLE PUBLICATION

The publication of a report, "Oxygen Relationships in Streams," has been announced by the Public Health Service at Cincinnati. This volume is being issued as technical report W58-2 and is available on request from the Robert A. Taft Sanitary Engineering Center, 4676 Columbia Parkway, Cincinnati 26, Ohio. The 194-page publication contains the proceedings of a seminar sponsored by the Water Supply and Water Pollution Control program in November 1957.

The contents include comprehensive coverage of many technical aspects of streams in regard to pollution as presented by a selected group of authorities and constitute a valuable reference on the subject.

STATISTICAL SUMMARY OF SEWAGE CHLORINATION PRACTICE IN THE UNITED STATES

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The Public Health Service has gathered and published statistics concerning water and sewage works in the United States since 1939. Basic documents have been published at irregular intervals; the latest *Inventory of Sewage and Industrial Wastes Facilities* (1) is now in press. Summarization of data contained in the 1957 "Inventory" was recently published (2).

This summary presents data on the practice of sewage chlorination in United States municipal sewage treatment works. Basic data are from the 1957 "Inventory" (1). A similar report summarizing chlorination practice in 1948 was published in 1950 (3).

The "Inventory" reports physical features of the treatment works. It does not contain data on operating features. Consequently, these data on chlorination practice report the ability of a plant to chlorinate and not necessarily that the process is used or with what frequency it is employed.

The basic tabular data are presented in Tables I, II, and III, in each of which the number of plants and the estimated population served by the various combinations of chlorination facilities are given. The three tables are arranged by states, by population groups, and by major drainage basins, respectively.

The drainage basins used are those developed by the Public Health Service in cooperation with the state water pollution control agencies. They are shown in Figure 1.

Table IV shows the number of facilities having chlorination and the population served. It also gives percentage comparisons with the total number of plants and population served. Corresponding data for 1948 are also shown. Table V presents comparable data for 1940, 1945, 1948, and 1957 and shows percentage change data for intervening periods.

Discussion

In 1957 over 2,200 plants serving almost 38 million persons were equipped with chlorination facilities. This is about 30 per cent of all treatment plants in the United States, and practically 50 per cent of the population served by treatment facilities. About 54 per cent of the population served by chlorination facilities was connected to plants employing chlorine gas without contact tanks. The next largest group—over 19 per cent—was served by facilities using liquid chlorine with a suitable contact chamber.

Contact tanks were reported present in 42.9 per cent of the plants having chlorination facilities; however, a group of plants representing about 11 per cent of the total did not report the type of facilities.

Chlorine gas is used in 71.5 per cent of the plants with chlorination facilities and hypochlorites are used in 6.4 per cent. The balance did not report the material used.

The report on the 1948 data (3) noted that there was considerable va-

TABLE I.—Number of Plants and Population Served by Various Methods of Chlorination—Arranged by States

State	Total		Chlorination With								Contact Tank—No Detail of Chlorine Preparation		No Detail in Inventory		Total Having Chlorination	
			Hypochlorite		Hypochlorite and Contact Tank		Liquid Chlorine		Liquid Chlorine and Contact Tank							
	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	No. of Plants (%)	Est. Pop. Served (%)
Alabama	18	118,740	1	1,200	—	—	13	90,440	2	24,500	—	—	2	2,600	15.0	21.5
Arizona	7	290,000	1	4,300	—	—	6	285,700	—	—	—	—	—	—	8.5	60.7
Arkansas	14	91,850	—	—	—	—	10	39,850	2	15,000	2	37,000	—	—	11.8	25.5
California	140	6,021,330	—	—	—	—	91	2,533,209	30	2,637,821	10	199,200	9	651,100	31.1	58.7
Colorado	11	657,720	—	—	—	—	6	637,400	—	—	—	—	5	20,320	10.2	65.2
Connecticut	33	718,630	—	—	—	—	15	490,450	12	114,850	—	—	6	113,330	50.0	59.7
Delaware	7	19,520	—	—	—	—	4	11,980	—	—	2	6,740	1	800	77.8	11.5
District of Columbia	1	1,240,000	—	—	—	—	—	—	—	—	—	—	1	1,240,000	100.0	100.0
Florida	129	1,018,015	1	800	—	—	47	643,860	81	373,355	—	—	—	—	68.6	90.1
Georgia	12	422,500	—	—	—	—	10	418,000	—	—	—	—	2	4,500	7.3	52.8
Idaho	23	105,000	—	—	—	—	6	35,400	17	69,600	—	—	—	—	44.2	86.5
Illinois	44	361,631	1	1,100	—	—	11	40,151	23	181,085	1	5,220	8	134,075	11.5	5.1
Indiana	60	1,348,732	—	—	2	1,500	31	1,040,697	19	271,325	—	—	8	35,210	43.5	68.1
Iowa	8	78,367	—	—	—	—	4	30,400	4	47,967	—	—	—	—	2.4	8.3
Kansas	1	45,000	—	—	—	—	—	—	1	45,000	—	—	—	—	0.4	4.7
Kentucky	40	234,235	1	1,200	—	—	28	192,225	8	35,930	—	—	3	4,880	47.6	26.7
Louisiana	39	275,542	—	—	1	350	21	88,332	14	173,860	2	5,500	1	7,500	54.2	79.3
Maine	2	1,460	1	1,340	1	120	—	—	—	—	—	—	—	—	10.0	2.6
Maryland	33	170,643	1	320	—	—	16	101,770	16	68,553	—	—	—	—	63.5	15.6
Massachusetts	26	1,264,920	1	200	—	—	16	972,700	5	130,700	—	—	4	161,320	38.2	49.1
Michigan	78	2,950,972	1	1,500	—	—	19	2,182,029	42	439,363	6	125,860	10	202,220	54.2	79.0
Minnesota	164	1,332,802	2	1,570	28	31,322	11	821,950	94	442,686	19	24,014	10	11,260	58.8	91.2
Mississippi	15	92,200	—	—	—	—	9	62,900	3	10,100	2	17,200	1	2,000	19.0	48.3
Missouri	11	38,100	1	910	—	—	7	24,300	2	4,890	—	—	1	8,000	4.7	6.5
Montana	6	27,690	—	—	—	—	5	27,400	1	290	—	—	—	—	7.3	18.6

TABLE I.—*Continued*

State	Total		Chlorination With								Contact Tank—No Detail of Chlorine Preparation		No Detail in Inventory		Total Having Chlorination	
			Hypochlorite		Hypochlorite and Contact Tank		Liquid Chlorine		Liquid Chlorine and Contact Tank							
	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	No. of Plants (%)	Est. Pop. Served (%)
Nebraska	2	2,300	—	—	—	—	2	2,300	—	—	—	—	—	—	1.2	0.7
Nevada	6	129,925	—	—	—	—	2	20,200	4	109,725	—	—	—	—	18.8	76.0
New Hampshire	8	27,750	—	—	—	—	6	26,750	—	—	—	—	2	1,000	53.3	53.0
New Jersey	176	1,952,281	—	—	—	—	9	35,300	28	259,860	111	1,136,196	28	520,925	78.6	49.6
New Mexico	3	12,100	—	—	—	—	—	—	2	12,000	1	100	—	—	4.3	2.4
New York	183	5,333,895	5	27,600	—	—	133	4,048,760	15	262,650	10	866,145	20	128,740	59.4	60.4
North Carolina	44	522,406	2	3,100	1	1,200	19	104,469	—	—	20	386,812	2	26,825	15.8	48.7
Ohio	88	2,975,326	1	1,150	—	—	26	429,170	—	—	3	13,280	58	2,531,726	29.6	61.6
Oklahoma	13	162,020	—	—	—	—	9	152,470	1	3,100	—	—	3	6,450	5.3	14.6
Oregon	84	347,730	2	1,300	2	200	47	235,750	33	110,480	—	—	—	—	71.8	45.6
Pennsylvania	149	1,539,280	4	4,400	2	12,600	44	569,710	41	338,185	29	421,060	29	193,325	51.4	36.0
Rhode Island	11	495,010	—	—	1	35,000	6	357,460	4	102,550	—	—	—	—	68.8	92.1
South Carolina	10	90,250	1	600	—	—	7	69,650	—	—	2	20,000	—	—	6.0	21.2
South Dakota	7	48,275	—	—	—	—	2	4,725	2	6,800	3	36,750	—	—	5.5	18.2
Tennessee	36	491,690	—	—	—	—	11	88,310	8	38,950	9	136,840	8	227,590	40.9	72.2
Texas	146	2,308,185	60	104,545	3	1,190	60	2,124,520	4	12,700	12	37,630	7	27,600	21.8	46.7
Utah	21	163,013	—	—	—	—	19	157,723	1	990	—	—	1	4,300	36.2	80.0
Vermont	2	8,400	—	—	—	—	1	8,100	1	300	—	—	—	—	25.0	23.8
Virginia	71	720,895	4	66,700	—	—	39	93,205	17	468,250	7	83,800	4	8,940	75.5	88.4
Washington	123	635,890	1	200	1	970	49	352,100	71	281,420	1	1,200	—	—	79.4	96.8
West Virginia	10	126,745	1	345	—	—	3	45,500	5	79,100	1	1,800	—	—	34.5	81.6
Wisconsin	99	797,470	5	4,800	2	840	51	661,515	39	127,535	—	—	2	2,780	29.7	37.6
Wyoming	2	18,800	—	—	—	—	1	15,000	—	—	1	3,800	—	—	5.0	15.6
Total	2,216	37,835,235	98	229,180	44	85,292	932	20,373,830	652	7,301,470	254	3,566,147	236	6,279,316	29.5	49.5

TABLE II.—Number of Plants and Population Served by Various Methods of Chlorination—Arranged by Population Groups

Population Group	Total		Chlorination With								Contact Tank—No Detail of Chlorine Preparation		No Detail in Inventory		Total Having Chlorination	
			Hypochlorite		Hypochlorite and Contact Tank		Liquid Chlorine		Liquid Chlorine and Contact Tank							
	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	No. of Plants (%)	Est. Pop. Served (%)
Under 500	146	80,515	20	6,645	20	5,369	45	45,432	37	10,453	9	2,316	15	10,300	18.1	29.4
500–1,000	246	182,320	26	17,900	14	8,613	71	51,684	95	77,215	16	12,063	24	14,845	18.6	21.3
1,000–5,000	921	2,177,417	45	79,385	6	6,810	378	927,286	296	692,045	106	268,056	90	203,835	26.6	32.0
5,000–10,000	340	2,365,174	2	11,750	1	6,000	166	1,261,904	78	501,790	52	324,615	41	259,115	39.4	42.7
10,000–25,000	292	4,082,876	4	48,500	2	23,500	126	1,796,425	92	1,244,819	41	573,537	27	396,095	49.1	48.5
25,000–50,000	127	3,991,809	—	—	—	—	61	2,030,924	34	925,195	18	504,280	14	531,410	63.8	67.1
50,000–100,000	54	3,365,985	1	65,000	1	35,000	27	1,701,215	11	845,540	6	350,280	8	368,950	54.5	53.4
Over 100,000	90	21,589,139	—	—	—	—	58	12,558,960	9	3,004,413	6	1,531,000	17	4,494,766	54.9	51.0
Total	2,216	37,835,235	98	229,180	44	85,292	932	20,373,830	652	7,301,470	254	3,566,147	236	6,279,316	29.5	49.5

TABLE III.—Number of Plants and Population Served by Various Methods of Chlorination—Arranged by Drainage Basins

Major Drainage Basins	Total		Chlorination With								Contact Tank—No Detail of Chlorine Preparation		No Detail in Inventory		Total Having Chlorination	
			Hypochlorite		Hypochlorite and Contact Tank		Liquid Chlorine		Liquid Chlorine and Contact Tank							
	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	No. of Plants	Est. Pop. Served	No. of Plants (%)	Est. Pop. Served (%)
Northeast	188	4,075,120	6	27,240	2	35,120	114	3,051,105	34	576,550	3	4,095	29	381,010	48.0	57.6
North Atlantic	441	8,900,889	7	69,420	1	12,500	137	3,352,430	92	1,115,363	142	2,373,206	62	1,977,970	69.9	52.4
Southeast	234	2,260,641	5	5,500	1	1,200	109	1,374,399	88	406,555	25	439,062	6	33,925	24.6	54.3
Tennessee River	25	406,485	1	1,200	—	—	10	81,355	4	26,900	6	85,240	4	211,790	29.4	73.1
Ohio River	204	3,028,582	4	4,445	3	1,600	98	1,634,017	39	313,840	16	170,590	44	904,090	34.1	54.7
Lake Erie	52	1,958,166	1	1,150	—	—	16	251,410	2	7,600	2	8,580	31	1,689,426	47.3	70.3
Upper Mississippi	253	1,940,515	7	7,170	26	19,872	56	1,246,796	125	492,078	21	31,734	18	142,865	21.9	19.1
Western Great Lakes	148	3,841,692	2	1,800	2	11,430	48	2,628,339	78	866,793	6	125,860	12	207,470	49.5	68.7
Missouri River	30	753,820	1	910	2	860	15	634,125	6	58,355	2	34,250	4	25,320	3.5	30.2
Southwest-Lower Miss.	94	772,842	6	23,580	1	350	49	465,852	21	202,410	8	58,200	9	22,450	11.8	22.5
Colorado River	18	380,030	1	4,300	—	—	11	304,015	4	68,715	—	—	2	3,000	11.7	55.0
Western Gulf	137	2,194,405	54	80,965	3	1,190	58	2,031,820	6	24,700	11	31,130	5	24,600	21.8	45.1
Pacific Northwest	230	1,124,910	3	1,500	3	1,170	102	622,450	121	498,590	1	1,200	—	—	69.9	70.4
California	135	5,997,833	—	—	—	—	88	2,521,509	28	2,626,024	10	199,200	9	651,100	32.8	59.1
Great Basin	27	199,305	—	—	—	—	21	174,208	4	16,997	1	3,800	1	4,300	26.0	59.9
Total	2,216	37,835,235	98	229,180	44	85,292	932	20,373,830	652	7,301,470	254	3,566,147	236	6,279,316	29.5	49.5

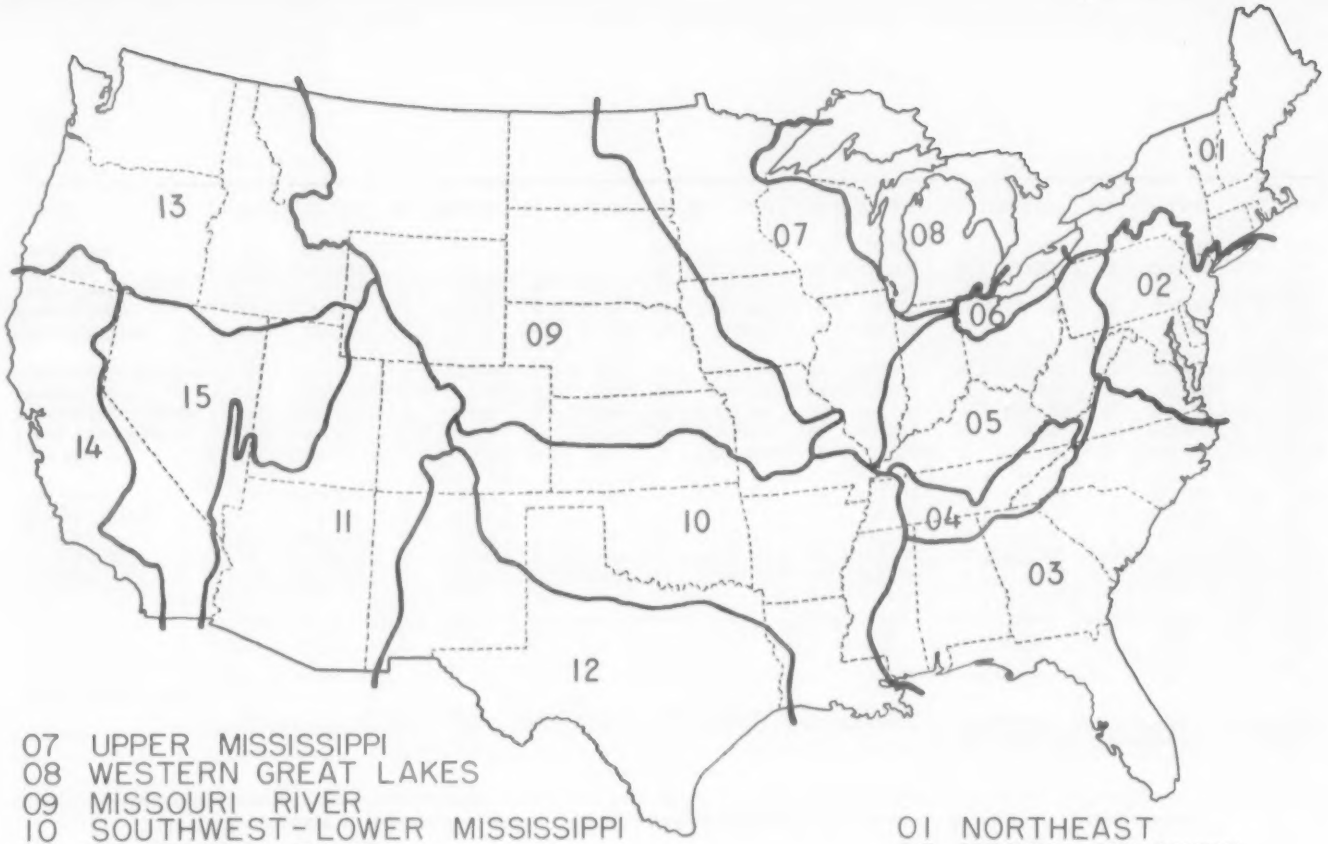

FIGURE 1.—Major river basins of the United States.

TABLE IV.—Number of Plants and Population Served by Chlorination Facilities—Arranged by Degree of Treatment

Plants	Minor Treatment		Primary Treatment		Intermediate Treatment		Secondary Treatment		All	
	No. of Plants	Est. Pop. Served (1000's)	No. of Plants	Est. Pop. Served (1000's)	No. of Plants	Est. Pop. Served (1000's)	No. of Plants	Est. Pop. Served (1000's)	No. of Plants	Est. Pop. Served (1000's)
Having chlorination	27	742	775	14,227	60	3,486	1,354	19,380	2,216	37,835
All plants	41	1,860	2,730	25,667	100	5,591	4,647	43,326	7,518	76,444
% of total having chlorination—1957	65.9	39.9	28.4	55.4	60.0	62.4	29.1	44.7	29.5	49.5
% of total having chlorination—1948	58.8	17.4	18.3	41.6	48.1	83.1	23.3	37.0	21.6	37.0

riation among the states in sewage chlorination practice, and that chlorination was practiced more frequently in the more populous states. The same situations held in 1957. New York and New Jersey reported the largest numbers of plants with chlorination facilities, and California and New York had the largest populations served. Only one state, North Dakota, reports no plants with chlorination facilities.

More than 440 plants in the North Atlantic drainage basin had chlorination facilities. While this is the largest number in any of the major basins, the percentage of total plants having chlorination facilities (69.9 per cent) is equalled in the Pacific Northwest basin. The Tennessee River basin, where 73.1 per cent of the population served by treatment works is also served by chlorination, has the highest percentage of population so served. The percentages for all basins are shown in Table III.

TABLE V.—Comparison of Plants Having Chlorination and Population Served for 1940, 1945, 1948, and 1957

Year	No. of Plants	Est. Pop. Served (1000's)	Total Having Chlorination		Change (%)	
			Plants (%)	Est. Pop. Served (%)	Plants	Est. Pop. Served
1940	1,127	14,336	20.2	35.3		
					12.0	11.8
1945	1,262	16,029	21.8	34.2		
					3.6	12.5
1948	1,307	18,037	21.6	37.0		
					69.5	109.8
1957	2,216	37,835	29.5	49.5		

In general the practice of employing sewage chlorination becomes more frequent as the size of community increases, although the percentages of total plants and population served are about the same in the larger groups. These percentages are given in Table II. It is interesting to note that in the three groups representing communities of largest population (over 25,000), over half the population served by treatment is connected to plants incorporating chlorination facilities.

Comparative data for 1940, 1945, 1948, and 1957 are shown in Table V. From 1940 to 1948 there was no major increase in the percentages of total treatment plants and population served by treatment for those facilities incorporating chlorination. However, between 1948 and 1957 there were marked increases. The proportion of total plants having chlorination increased from 21.6 per cent in 1948 to 29.5 in 1957 and population served increased from 37.0 per cent to 49.5 per cent. The percentage increase in numbers of plants and total population served between 1948 and 1957 was even more pronounced—69.5 and 109.8 per cent, respectively.

Certain rather significant trends in sewage chlorination practice are apparent in a review of these statistics. As population moved toward greater urbanization and the development of metropolitan areas, there was a con-

comitant increase in the number of persons served by chlorination facilities. There are no valid reasons to assume that this trend will be reversed in the future. What impact this may have on the cost of over-all treatment facilities cannot be definitely ascertained; however, the assumption appears valid that it will be significant.

Summary

Statistical data from the 1957 *Inventory of Municipal and Industrial Waste Facilities* in the United States are presented for sewage chlorination practice. Numbers of plants and estimated population served for various types of chlorination facilities are arranged by states, population groups, and major drainage basins. Over 2,200 plants serving approximately 38 million persons are equipped to chlorinate sewage at some stage of the treatment process. Such facilities are most common in the more populous and highly urbanized states. Since 1948, the population served by plants incorporating chlorination facilities has increased almost 110 per cent. The number of such plants has increased about 70 per cent.

References

1. "Inventory of Municipal and Industrial Waste Facilities." Public Health Service Publication No. 622, in press.
2. Thoman, J. R., and Jenkins, K. H., "Statistical Summary of Sewage Works in the United States." Public Health Service Publication No. 609 (1958).
3. Thoman, J. R., "Statistical Summary of Sewage Chlorination Practice in the United States." THIS JOURNAL, **22**, 9, 1128 (Sept. 1950).

TRAINING COURSES

University of North Carolina

The Department of Sanitary Engineering of the University of North Carolina and the North Carolina State Board of Health will conduct their Fifth Annual Seminar on Radiological Health, Jan. 26–28, 1959.

Information may be obtained from Professor Emil T. Chanlett, Department of Sanitary Engineering, School of Public Health, University of North Carolina, Chapel Hill, N. C.

Public Health Service

A partial listing of training courses being offered during the winter season at the Public Health Service's Robert A. Taft Sanitary Engineering Center appeared in THIS JOURNAL on page 1416 of the November issue. Additional courses being offered are as follows:

Mar. 2–13	Basic Radiological Health
Mar. 2–13	Water Quality Management—Sanitary Engineering Aspects
Mar. 16–25	Environmental Health Aspects of Nuclear Reactor Operations

Applications should be addressed to the Chief, Training Program, Robert A. Taft Sanitary Engineering Center, 4676 Columbia Parkway, Cincinnati 26, Ohio, or to the appropriate Public Health Service Regional Director.

SURVIVAL OF *SALMONELLA TYPHOSA* DURING ANAEROBIC DIGESTION *

I. EXPERIMENTAL METHODS AND HIGH-RATE DIGESTER STUDIES

By Ross E. McKinney, Harold E. Langley,† and Henry D. Tomlinson ‡

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Anaerobic digestion has been used for many years to stabilize sewage sludges. Digester retention times have been shortened to less than one month by (a) heating the sludge mass to an optimum temperature for bacterial metabolism, (b) recirculating the digester contents, and (c) using two-stage digestion. Recently, the concept of high-rate digestion has been introduced. This method of operation is based on close temperature control, thorough mixing, and either decreased retention time for normal sludges or the feeding of concentrated, pre-thickened sludges. Sawyer and Roy (1) have shown that a retention time as short as six days is possible for the digestion of primary sewage sludge of normal concentration when operating conditions are carefully controlled. The economic advantages to be gained through the use of high-rate sludge digestion are obvious. At the same time the advent of high-rate digestion has caused concern over the possible increased survival of pathogenic bacteria during the process due to the short retention periods.

One of the most important functions of any sewage treatment process is to act as a protective barrier against the spread of infectious diseases. Early studies on the survival of various pathogenic organisms (2) (3) (4) (5) have shown that these organisms tended to collect in sewage sludge and, although a rapid die-off occurred, some survived for a period of several weeks. There was no indication in the literature of quantitative data related to pathogen survival under anaerobic conditions in sludge digesters. The purpose of this paper is to present an analytical method for the quantitative enumeration of *Salmonella typhosa* and related enteric bacteria and to show their degree of survival during high-rate anaerobic sludge digestion.

Differential Media

One of the major problems in the quantitative enumeration of enteric bacteria in sewage and sewage sludge was the selection of suitable media that were specific for the desired organisms. Certain commercial media were available which had been used in selective culturing of enteric bacteria. These media had been prepared in accordance with formulas published in the various bacteriological journals from extensive research data. In the present study, the eight prepared media listed below were investigated.§

* Presented at the Spring Meeting of the New England Sewage and Industrial Wastes Assn.; Gardner, Mass.; June 4–5, 1958.

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1. Tryptone Glucose Extract Agar (TGA)—general bacteria.
2. Eosin Methylene Blue Agar (EMB)—*Enterobacteriaceae.*
3. Salmonella-Shigella Agar (SS)—*Salmonella* and *Shigella.*
4. Bismuth Sulfite Agar (BS)—*Salmonella typhosa.*
5. Violet Red Bile Agar (VRB)—coliforms.
6. MacConkey's Agar (MacC)—*Enterobacteriaceae.*
7. Brilliant Green Agar (BG)—*Salmonella.*
8. Desoxycholate Lactose Agar (DesL)—*Enterobacteriaceae.*

Evaluation of Media

The efficiencies of the media were evaluated for differentiation and quantitative enumeration of the following five enteric bacteria.*

1. *Escherichia coli* (*E. coli*), ATCC #10053.
2. *Aerobacter aerogenes* (*A. aerogenes*), ATCC #129.
3. *Salmonella schottmeulleri* (*S. schottmeulleri*), ATCC #9282.
4. *Salmonella typhosa* (*S. typhosa*), ATCC #9993.
5. *Shigella dysenteriae* (*Sh. dysenteriae*), ATCC #9665.

The bacteria were grown for 24 hr in lactose broth tubes at 37°C. Serial dilutions were prepared from the lactose broth cultures and triplicate pour plates were made in each of the test media. The initial investigation showed that typical reactions for many of the bacteria did not occur during subsurface growth on standard pour plates. The differential characteristics developed only when the organisms were grown on the surface of the media.

The use of surface growth for differentiation and enumeration was not a new technique but rather one which had been discarded because of a lack of precise instruments. Modern equipment allowed Pomerales-Lebron and Fernandez (6) to revise the surface growth method for bacterial enumeration in a large number of samples. Gaudy (7) made a study of the quantitative counts between surface growths and standard pour plates and found that the surface growth method gave as accurate results as standard pour plates. The techniques used in this study were essentially the same as those used by Gaudy. They are as follows:

1. Sterile nutrient agar poured into sterile petri dishes.
2. Solidified agar plates dried for 48 hr at room temperature.
3. Plates inoculated with 8 0.02-ml spots per plate.
4. Plates incubated at 37°C for 24 to 48 hr.

The purpose of drying the agar plates for 48 hr prior to use was to reduce the surface moisture, thereby permitting rapid absorption of the inoculum. The 0.02-ml spots were measured from a graduated 0.2-ml pipette. At first there was difficulty getting precise measurement of the 0.02-ml spots; but the use of a microscrew attachment permitted rapid, precise measurement of the 0.02-ml spots. Each plate was divided into two sections with four spots on each section. Actually, four spots were made on each dilution. In this way, two dilutions were set up on each plate. The bacteria counts were made from the sum of the four spots. To convert the counts to bacteria per milliliter it was necessary to multiply the plate count by 12.5, since the plate count represented the bacteria per 0.08 ml, and then to multiply by the appropriate dilution factor.

It can readily be seen that the surface growth technique which will be called the "Spot Plate" method is limited to samples containing a relatively high bacterial population. The

* Obtained from American Type Culture Collection, Washington, D. C.

most probable range of bacteria per spot has been found to be between 5 and 50. This means that the minimum plate count should be 20 and the minimum counts per milliliter should be 250. Thus, while the spot plate technique can be used to make counts on materials with high bacteria populations such as sewage and sewage sludges, it is not suitable for use on clean waters where the bacteria population is below 250 per ml.

The spot plate method as used in this study was designed to permit enumeration of the facultative bacteria, which have the ability to grow either in the presence or the absence of gaseous oxygen. All of the enteric bacteria and most of the common bacteria responsible for the degradation of organic matter in sewage are facultative bacteria. For this reason it was not necessary to incubate the spot plates under anaerobic conditions.

The five test bacteria were grown for 24 hr in lactose broth at 37°C. Spot plates were made on the eight test media in quadruplicates. Counts were made after 24-hr incubation at 37°C. A typical set of results obtained during the media evaluation study is shown in Table I. The TGA counts were considered as the base counts since this medium contained all necessary nutrients for normal bacteria growth. EMB gave good recovery of all *Enterobacteriaceae* with the exception of *Sh. dysenteriae* and permitted differentiation of *E. coli* and *A. aerogenes*. The SS agar was not quantitatively satisfactory for any of the test bacteria and was discarded. BS was highly selective for *S. typhosa* but was not 100 per cent inhibitive to all test bacteria. VRB gave fair recovery of all *Enterobacteriaceae*, but in view of the better results obtained on EMB, the VRB was discarded. MacC agar did not yield satisfactory results and was discarded. While BG did not give quantitative recovery of *S. schottmuelleri*, it did give excellent recovery of *E. coli*. DesL did not give any better results than EMB and was discarded. Thus, four media, TGA, EMB, BS, and BG, were selected for further studies.

The initial media evaluation study showed that the BS agar could not be handled in the same manner as the other agars. The 48-hr drying period had to be reduced to 24 hr or else the BS agar lost its selective properties for *S. typhosa*. Later in the investigation it was found that the BS agar plates could be dehydrated in the refrigerator and stored at 4°C for up to a week without affecting its activity. Reduced activity in the agar could easily be detected by a change in the color of the agar from a light green to a bright green.

Recovery from Sludge

Once the differential media were selected, a procedure for the recovery

TABLE I.—Average 24 Hr, 37°C Counts of Enteric Bacteria on Quadruplicate Spot Plates

Media	Bacteria Counts Per Ml $\times 10^{-6}$				
	E. coli	*A. aerogenes*	*S. schottmuelleri*	*S. typhosa*	*Sh. dysenteriae*
TGA	440	800	540	280	120
EMB	480	830	540	270	85
SS	0	190	210	180	1
BS	210	0	380+	260	0
VRB	400	620	450	280	70
MacC	390	710	350	280	30
BG	420	0	210	0	0
DesL	400	850	450	270	70

TABLE II.—Recovery of Pure Culture Enteric Bacteria from Sterile Sewage Sludge

Media	24 Hr, 37°C Bacteria Counts Per Ml $\times 10^{-4}$									
	E. coli		*A. aerogenes*		*S. schottmuelleri*		*S. typhosa*		*Sh. dysenteriae*	
	Control	Sterile Sludge	Control	Sterile Sludge	Control	Sterile Sludge	Control	Sterile Sludge	Control	Sterile Sludge
(*a*) Run No. 1										
TGA	550	640	1100	1060	450	480	300	250	76	55
EMB	540	510	1280	1350	450	450	260	340	64	64
BS	680	410	1100	1470	—	390	310	290	0	0
BG	100	290	0	0	330	310	0	0	0	0
(*b*) Run No. 2										
TGA	560	510	1000	1150	590	600	290	310	145	181
EMB	680	610	990	1080	610	700	290	300	181	180
BS	700	450	900	950	610	820	250	250	0	0
BG	600	420	0	0	280	420	0	0	0	0

and quantitative enumeration of the enteric bacteria from sewage sludge was developed and tested to determine the accuracy of the analytical method. The bacteria were grown in lactose broth cultures for 24 hr at 37°C. A 1-ml sample from each culture was transferred to a separate 9-ml sample of sterile raw sewage sludge, mixed, and treated in the following manner:

1. Transferred to a Waring Blendor with 90 ml of sterile dilution water.
2. Homogenized for 60 sec.
3. Settled for 5 min.
4. One ml of supernatant withdrawn from below scum layer.
5. Serial dilutions prepared.

Spot plates were prepared from each sample on all test media and from the

TABLE III.—Recovery of Individual Bacteria from a Known Mixture of Enteric Bacteria in Sterile Sludge

Media	*E. coli*		*A. aerogenes*		*S. schottmuelleri*		*S. typhosa*		*Sh. dysenteriae*		*Total Counts**	
	Added	Recovered	Added	Recovered	Added	Recovered	Added	Recovered	Added	Recovered	Added	Recovered
(*a*) Run No. 1												
TGA	225	—	150	—	320	—	195	—	215	—	1105	990
EMB	290	210	140	180	310	—	170	—	95	—	1005	890
BS	55	210	155	—	360	250	180	180	0	0	750	810
BG	230	280	0	0	245	120	0	0	0	0	475	400
(*b*) Run No. 2												
TGA	290	—	160	—	300	—	235	—	175	—	1160	1040
EMB	250	160	140	200	250	—	240	—	180	250	1060	1000
BS	200	190	155	110	260	260	170	150	0	0	785	880
BG	240	230	0	0	210	8	0	0	0	0	450	340

* Total recovered counts include those colonies not distinctive for positive identification.

TABLE IV.—Enumeration of Enteric Bacteria in Raw Sludge and Digesting Sludge (4-Day Average) (Bacteria Counts per Ml $\times 10^{-4}$)

Media and/or Bacteria	Raw Sludge	Theoretical Retention Period of Digesters				
		20 Days	15 Days	10 Days	8 Days	6 Days
TGA	36,000	1,000	1,600	1,900	2,500	2,900
EMB	2,500	71	125	60	79	84
BS	250	4	3	8	11	7
BG	260	2	12	7	30	21
E. coli	200	3	1	2	8	5
A. aerogenes	250	10	4	1	3	5
S. typhosa	0	0	0	0	0	0

lactose broth cultures without homogenization. The plates were incubated for 24 hr at 37°C prior to counting.

There was good recovery of all five test organisms from the sludge, indicating that the homogenization process did not kill the bacteria and that there was no significant adsorption of the bacteria on the solids that settled. Typical data from two runs are presented in Table II. It is significant to note that *Sh. dysenteriae* gave good results on EMB.

The same procedure was followed to determine the recovery of the five test organisms from a mixture of the pure cultures inoculated into sterile sludge. It was found that 48-hr counts were more accurate than 24-hr counts when mixtures of organisms were in the samples. The results of two runs are presented in Table III. Considering the nature of raw sludge, identification of the individual bacteria was good in these runs.

Survival in High-Rate Digesters

After establishing a satisfactory method for the recovery, differentiation, and enumeration of enteric bacteria in sewage sludge, it was necessary to determine the bacterial populations existing in raw sewage sludge and in digesting sludge. Laboratory digesters had been set up under various operating conditions and were in normal operation. The engineering data on the operation of these laboratory digesters have already been reported by Sawyer and Roy (1). These digesters were six-liter units, operated on a fill-and-draw basis. Each digester was fed raw sewage sludge from a municipal sewage treatment plant* at 12-hr intervals. Five digesters were operated with theoretical retention periods of 6, 8, 10, 15, and 20 days. Although each digester was fed on a twice a day basis, gas recirculation was employed to keep the contents of the entire digester completely mixed at all times.

Examination of raw sludge and sludge from each digester indicated that the bacteria counts were low. The results of one series of tests are shown in Table IV. The average results of a four day's operation indicated that the total facultative bacteria in the digested sludges were a function of the bacteria in the feed sludge, which in turn were a function of the available organic matter. The enteric bacteria did not show a clear-cut variation but rather held relatively level even though the concentration of enteric bacteria in the feed increased with shortened retention periods.

The most significant item was that the three selective media were not as selective as desired. Many different bacteria grew on the agar plates. In order to determine the predominant non-typical bacteria, colonies were selected from each type of media and identified according to the procedures

* Nut Island, Boston, Mass.

set forth by the Society of American Bacteriologists (8). All of the media showed similar contaminants which belonged to the families *Pseudomonadaceae, Achromobacteriaceae,* and *Enterobacteriaceae.* The *Pseudomonadaceae* are common facultative sewage bacteria, which easily metabolize all types of organic matter. The *Achromobacteriaceae* are also common facultative sewage bacteria, which primarily metabolize proteins. These bacteria would be expected to be the types responsible for the degradation of organic matter in the so-called "acid production phase" of digesters.

Single Inoculum

In view of the fact that raw sewage sludge did not contain the enteric bacteria in sufficient numbers to permit reasonable counts in the digested sludge, a large inoculum of pure bacteria was added to the sludge which was fed to the digesters. The five bacteria used in the previous studies were grown on the surface of TGA plates for 24 hr at 37°C, harvested with a rubber policeman and suspended in 50 ml of water. The 50-ml bacteria suspension was added to the sludge to be fed to the digesters and mixed. Bacteria counts were made on the 50-ml suspension and on the sludge-bacteria mixture to be certain that the technique was satisfactory. Analyses were made on the sludge removed from each digester for a period of six days. These analyses were made by placing 20 ml of sludge in 180 ml of dilution water in the Waring Blendor and then following the technique already outlined. The initial dilution gave a 1:10 final dilution which meant that the minimum reliable bacteria count would be 2,500 per ml and the absolute minimum count would be 125 per ml. The results of this study showed a very rapid die-off of bacteria. Because of the voluminous nature of the data on the bacteria studied and the similarity of results only the data for *S. typhosa* are presented in Table V.

The initial inoculum of *S. typhosa* in the digesters ranged from 1.1×10^7 to 3.8×10^7 per ml. Within 12 hr the *S. typhosa* count dropped to 0.3 to 17 per cent of the original inoculum. The survival of *S. typhosa* appeared to be a factor of the retention period which actually was a measure of the organic concentration available for bacterial metabolism. The same appeared true of all of the enteric bacteria studied.

Continuous Daily Inoculum

It appeared that a single inoculum of enteric bacteria declined rapidly but the number of bacteria surviving was still sufficiently large to raise the question of ultimate survival level

TABLE V.—Survival of *S. Typhosa* in Digesting Sludge from a Single Inoculum of a Mixed Pure Culture of Enteric Bacteria (Bacteria Counts per Ml $\times 10^{-4}$)

Day	Raw Sludge	Theoretical Retention Period of Digesters				
		20 Days	15 Days	10 Days	8 Days	6 Days
0	45,000	1,120	1,500	2,250	2,810	3,750
0.5	—	6.2	5.0	380	—	440
1.0	0	2.5	0	100	180	250
1.5	1.2	0.6	6.2	11	25	50
2.0	12	0.1	0.1	0.6	0	22
2.5	0	0	0.1	0	15	10
3.0	0	0	0.1	0.1	1.2	0.4
3.5	0	0	0.1	0	0.1	0
4.0	—	0.1	0	0	0	0
5.0	0	0	0.1	0.1	0.1	0
6.0	—	0.1	0	0.4	0.1	0.2

TABLE VI.—Daily Pure Culture Inoculums of *Salmonella Typhosa* into Six-Day and Twenty-Day Digesters (Bacteria Counts per Ml $\times 10^{-3}$)

Day of Run	Six-Day Digester		Twenty-Day Digester	
	Initial Count	Count After 24 Hr	Initial Count	Count After 24 Hr
1	6.3	0.6	15.0	0.5
2	58.5	2.3	47.5	2.1
3	132	35.0	80.0	4.0
4	219	46.0	224	3.5
5	158	22.0	113	11.0
6	128	5.5	120	6.1
7	615	17.0	616	55.0
8	744	81.0	782	75.0
9	798	240	801	70.0
10	480	39.0	347	33.0
11	493	95.0	491	65.0
12	340	0	322	0
13	590	0	590	5.0
14	460	130	470	0
15	230	110	120	29.0
16	692	24.0	628	60.0
17	1320	310	1360	230
18	720	230	680	18.0
19	740	63.0	568	2.5
20	162	45.0	112	0
21	168	7.0	130	0
22	1110	42.0	1100	12.0
23	315	59.0	291	2.5
24	759	98.0	712	1.7

when the digesters were subjected to continuous daily inoculation. In view of the fact that the survival of enteric bacteria depended on the retention period of the digester, this phase of the study was carried out on the 6-day and 20-day digesters. The digesters were fed on a once a day schedule instead of a twice a day schedule as before. *S. typhosa* was used as the test organism because of its obvious health importance. Daily inoculations with *S. typhosa* were made over a 24-day period. A 50-ml suspension of *S. typhosa* prepared as in the previous study was put directly into each digester at the time of feeding. Counts were made daily on the inoculums and on the sludges removed from the digesters prior to feeding.

The data on this study are given in Table VI. There was a definite variation in the day to day results. The initial counts presented in the table are based on the contents of the digesters and represent the total *S. typhosa* per ml of sludge in the digesters at the beginning of each 24-hr period. This gave an average *S. typhosa* population after feeding of 44.7×10^4 per ml per day in the 20-day digester and 47.7×10^4 per ml per day in the 6-day digester. The digested sludge from the 20-day digester contained an average *S. typhosa* population of 3.4×10^4 per ml per day, a decrease of 92.4 per cent. The digested sludge from the 6-day digester contained an average of 7.7×10^4 per ml per day, or a decrease of 84.0 per cent.

Discussion

The quantitative enumeration of enteric pathogens in sewage and sewage sludge has long proved to be a difficult task. Direct enumeration of the enteric pathogens has been hampered by the overgrowth of the desired bacteria by less fastidious bacteria. The use of inhibitive media usually has resulted in suppression of the desired bacteria, as well as the undesired bacteria.

It has been shown that it is possible to utilize biochemical reactions in some selective media to quantitatively enumerate certain enteric bacteria. The three enteric bacteria which could be easily identified were *E. coli*, *A. aerogenes*, and *S. typhosa*. *E. coli* and *A. aerogenes* both presented typical growth characteristics on EMB agar plates. The green metallic sheen of *E. coli* on EMB agar could be contrasted to the black metallic sheen of *S. typhosa* on BS agar. Production of the special biochemical characteristics of the enteric bacteria depended on aerobic growth on the agar surface. For this reason the spot plate technique was readily adapted for the quantitative enumeration of these enteric bacteria in sewage sludge.

The problem of overgrowth of the desired bacteria by non-enteric bac-

teria was a major one depending on the total bacteria population per spot. A large bacterial growth reduced the inhibitory effect of the selective agar and permitted the non-enteric bacteria to overgrow the enteric bacteria. Best results were obtained with only 5 to 10 bacteria per spot. The small number of bacteria permitted maximum effect of the inhibitors on non-enteric bacteria. At these bacterial densities it was a problem to obtain a satisfactory count of the desired organism. On EMB agar the portion of *A. aerogenes* ranged from 2 to 50 per cent of the total EMB count. At the same time *E. coli* ranged from 0 to 10 per cent. On a plate count of 40 organisms, the maximum *E. coli* count was only 4 organisms. This was below that required for a statistically reliable count. With *S. typhosa* the counts ranged from 0 to 60 per cent of the total BS counts. For all significant results the *S. typhosa* count was at least 25 to 35 per cent of the total BS count. The ability to obtain a satisfactory count on *S. typhosa* was one of the major reasons for concentrating on this enteric bacterium.

Efforts to obtain data on normal sewage sludge were unsuccessful since Boston sewage sludge did not contain sufficient numbers of the common enteric bacteria to give reliable counts. Therefore, it was necessary to increase artificially the enteric bacteria population in the feed sludge. However, it was recognized that such an artificial increase in enteric bacteria would not persist but would decrease rapidly. The use of a single inoculum of enteric bacteria raised the facultative bacteria population by a factor of three from 6.5×10^8 to 18.0×10^8 bacteria per ml in the raw sludge. The normal facultative bacteria population was reached in 24 hr in the 15- and 20-day digesters, in 36 hr in the 10-day digester, and in 60 hr in the 8- and 6-day digesters. Thus, it was that with additional organic matter in the shorter retention period digesters, the enteric bacteria were able to survive longer. The data given for *S. typhosa* showed this relationship quite definitely. The decline of *S. typhosa* followed the normal log death pattern. The relative death rates for the digesters were 4, 4, 2.4, 0.8, and 1.2 for the 20-day, 15-day, 10-day, 8-day, and 6-day digesters, respectively. It appeared that survival was a factor of the particular digester. The rate of die-off of *S. typhosa* was fastest in the digester with the longest retention period, hence the least food.

Continual addition of *S. typhosa* to the 20-day digester for 24 days gave an average daily population of this organism in the digester at the beginning of a 24-hr period of 44.7×10^4 per ml. At the end of a 24-hr period the digested sludge contained an average typhoid population of 3.4×10^4 per ml. The 6-day digester had an average daily population at the beginning of 24 hr of 47.7×10^4 per ml while the population in the digested sludge at the end of 24 hr contained 7.7×10^4 per ml. The rate of die-off was 1.1 for the 20-day digester and 0.8 for the 6-day digester.

It appears that the survival of *S. typhosa* is primarily a function of the initial population in the raw sludge, the available food, and the retention period in the digester. The initial bacteria population is determined by the characteristics of the sludge and cannot be controlled. The engineer can adjust the digester retention period but only within narrow limits. The major problem revolves around the availability of food for *S. typhosa* in digesting sludge which includes competition for the food by other forms of life. This phase is the subject for further investigation.

Summary

1. The spot plate technique with selective media can be used for the

quantitative enumeration of certain enteric bacteria.

2. Eosin Methylene Blue agar can be used for enumeration of *E. coli* and *A. aerogenes*.

3. Bismuth Sulfite agar can be used for enumeration of *S. typhosa*.

4. Boston sewage sludge did not contain sufficient numbers of enteric bacteria for quantitative enumeration before and after digestion.

5. Addition of large quantities of enteric bacteria to anaerobic digesters with variable retention periods resulted in a rapid die-off of the enteric bacteria.

6. Continual addition of *S. typhosa* to a 6-day and a 20-day digester resulted in greater survival in the 6-day digester than in the 20-day digester, primarily due to the difference in retention period.

7. High-rate digestion of sewage sludge with retention periods between 6 and 20 days should not result in a significant increase in the health hazard from enteric bacteria.

Acknowledgment

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BRITISH PUBLICATION OFFER

The Institute of Sewage Purification (England) recently approved the sale of the *Journal and Proceedings of the Institute of Sewage Purification* to members of Federation Member Associations at an appreciably lower figure than quoted to other prospective purchasers who are not members of the Institute.

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Industrial Wastes

SOIL ADSORPTION OF RADIOACTIVE WASTES AT LOS ALAMOS

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The disposal of radioactive wastes by discharge to the ground has been practiced at Oak Ridge (1), Hanford (2), and Savannah River (3). During the early years of operation at Los Alamos, N. Mex., all wastes were discharged to seepage pits or to canyons. About six years ago this practice was stopped and chemical precipitation treatment plants (4) were installed. The areas receiving these plutonium-bearing wastes have been repeatedly monitored since that time, and no appreciable movement of plutonium through the soils has been noted. It has been observed, however, that the concentration of plutonium in the soil of a canyon receiving low-level wastes has progressively moved downstream. This concentration is not high and, although it is measurable, it is still within acceptable tolerance levels. The movement has not been extensive and is confined within the limits of the Los Alamos Project. Because there was some movement, it was deemed advisable to investigate the travel of plutonium through the local soils under varying conditions. Since there is a possibility that wastes containing strontium-90 and cesium-137 might be produced by the Laboratory in the near future it was decided to investigate these isotopes as well.

The Pajarito plateau, upon which Los Alamos is located, is underlain by Bandelier tuff erupted from the Jemez volcano during a recent geologic period. The Bandelier tuff has been subdivided into three member units which, from youngest to oldest, are the Tshirege, Otowi, and Guaje members. The Tshirege member forms the massive pinkish-orange colored cliffs that are the canyon walls in the Los Alamos area. It ranges in thickness from 100 to 200 ft near the Rio Grande to about 1,000 ft under the town site and shows general, irregular jointing and locally well-developed columnar joints. The Otowi and Guaje members, ranging in thickness up to about 200 and 50 ft, respectively, underlie the Tshirege throughout most of the plateau and are best exposed in the lower reaches of the canyons which are cut into the plateau.

The Tshirege member of the Bandelier tuff is composed mainly of welded tuff resulting from two or three ash flow eruptions from the Jemez volcano. The rocks of the Tshirege member generally are porous and friable but only slightly permeable. The permeability varies from 1 to 5 gpd/sq ft under one foot head. The ion exchange capacity for the Tshirege member, which was the tuff selected for this study, varies from 0.5 to 3 millequivalents per 100 grams. The Otowi member is a single thick pumice flow with some ash-fall and water-washed debris at the top, in some locations.

The Guaje member consists of massive unconsolidated pumice.

Methods

Cylindrical cores of tuff about 4¾ in. in diameter and varying in length from 4 to 18 in. were cut from unweathered rock with a core drill. The cores were sealed in a neoprene jacket which extended 3 in. above the upper surface of the core. A 4-in. lucite tube was inserted in the open jacket and served as a reservoir for the applied spike solution. Solutions of the respective nuclides were prepared so that 1×10^6 cpm/l were obtained. The flow of solution was controlled by adjusting the length of a tube attached to the neck of one-gallon jugs which contained the various spikes. Flow was regulated by adjusting the head so that 100 to 200 ml/hr of effluent would be collected in a glass dressing jar equipped with a delivery spout and delivered to a second gallon jug. The arrangement is shown in Figure 1. One of the set-ups is shown to use a polyethylene jug and receiving reservoir. The use of this material was necessitated by the determination of silicon, since it was felt this element might have some bearing on the retention or release of the various nuclides.

Samples were collected at 24-hr intervals or as required and the volumes recorded. At the time of sample collection 1 ml of each sample was plated on a stainless steel planchet, dried, and counted in an alpha or beta counter as required; gamma counts were determined on a 10-ml sample of the effluent. With strontium solutions, in many cases, original plates were counted two weeks later to determine the growth of yttrium. In the case of those effluents containing a mixed spike, radiochemical separations were made.

When increasing activity of the effluent indicated breakthrough of the nuclide, the core was dismantled, dried and autoradiographs made to deter-

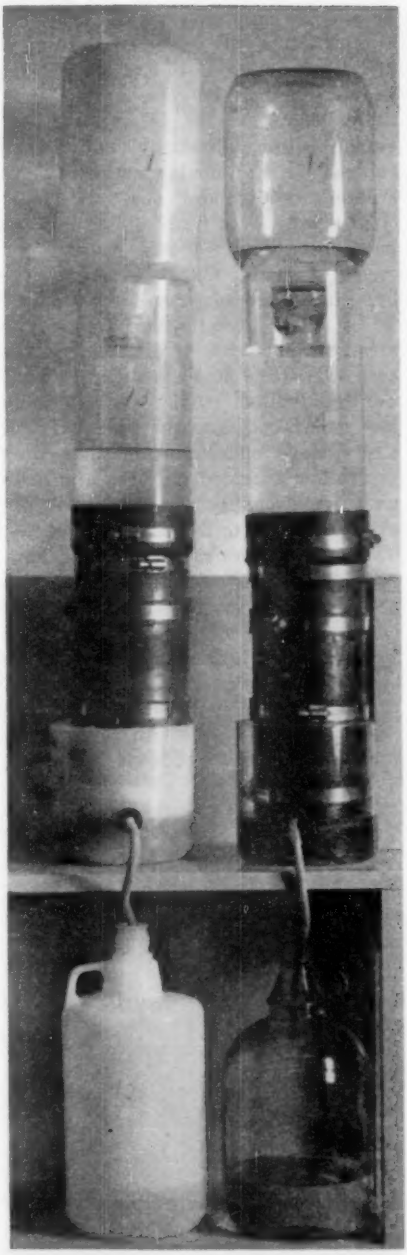

FIGURE 1.—Laboratory apparatus.

mine the distribution of the nuclide within the core. With some cores the application of the nuclide was stopped and leach solutions of various cations were applied to the core.

Determinations of pH, nitrate, calcium, sodium, alkalinity, and silicon content were made according to "Standard Methods" (5).

The weight of radioactive isotopes used in a study of this type is extremely small. For example, the drinking water tolerance for plutonium is 1.5×10^{-6} μc/ml which amounts to about 20 parts per trillion and in the case of Sr^{90} the figure is about 50 parts per quadrillion. At these extremely low concentrations, the chemistry of the various elements sometimes does not follow accepted patterns and ordinary ion exchange phenomena do not always pertain to the particular study. The removals are rather efficient, however, and it is possible, by passing a cesium spiked solution through a tuff core to reduce the concentration from 2×10^{-8} mg/l to 2×10^{-11} mg/l. It is obvious from this that the concentration and nature of the stable ionic components of the water will be the determining factors in the ability of tuff, or any soil, to retain radionuclides.

Results

Pu^{239} Cores

Seven cores of varying length were fed water spiked with 1×10^6 cpm/l of Pu^{239} as $Pu(NO_3)_4$. The amount of water fed varied from 100 to 380 l and the time of the test varied from two to six months. In every case the retention of the plutonium was in excess of 96 per cent. The spike was added to tap and distilled water and there was no apparent difference between the two. An analysis of Los Alamos tap water is shown in Table I. In the case of the core receiving 380 l of water this amounts to an application of 380×10^6 cpm and represents about 1,520 in. of water or some 90 yr of Los Alamos rainfall.

TABLE I.—Analysis of Los Alamos Tap Water

Constituent	Concentration (ppm)
Phen. alk.	0
M. O. alk.	116
Total hardness	24
Calcium	9
Magnesium	0.4
Sodium	51
Chloride	5
Fluoride	1.2
Nitrate nitrogen	1
Sulfate	4.5
Silica	35
Total solids	214

Plutonium, because of its high atomic weight and valence, can be expected to be tightly bound on any ion exchange material and replace many other ions. The ion exchange capacity of the tuff cores was exhausted after the passage of only a few liters of tap water, yet the plutonium was retained in a small portion of the core even after several hundred liters had passed through.

Autoradiographs were made by placing photographic film on cores that were cut in half. As can be seen in Figure 2 the activity penetrated to a depth of about 2 in. At this rate it is highly improbable that any plutonium, discharged in this form, would reach the Los Alamos ground water some 1,000 ft below ground surface in the foreseeable future. It should also be noted that there are several "hot" spots (white) in the radiograph which indicate the presence of localized concentrations of high ion exchange material such as montmorillonite clays.

Later attempts were made to leach out the plutonium already adsorbed on the cores by solutions of sodium, calcium, and magnesium in concentrations of 100 ppm as well as a saturated solution of carbon dioxide. None of these solutions removed appreciable amounts of plutonium.

Since this study was directed toward

FIGURE 2.—Autoradiograph of tuff core—Pu^{239} studies.

basic work very little effort was expended on actual wastes or complexing agents. It has been pointed out that plutonium complexes quite easily and in this condition is removed from solution only with great difficulty (4). It is to be expected that, under these conditions, it would not be retained by soils.

Dilutions of plutonium salts in basic or slightly acid solutions show a tendency to form polymerized, hydrated molecules which are extremely large (6). These polymerized molecules are entirely too large to enter into an ion exchange reaction and could be expected to pass through almost any type of soil. In addition to this effect other experiments have indicated that complexing agents such as: versene, citric acid, soaps, etc., have an adverse effect on the retention of plutonium in tuff. The data are not complete enough to report on at this time. However, it is known that such agents do interfere with removal of plutonium from liquid wastes by chemical precipitation and they might be expected to show a comparable effect in soils. Experiments on the effect of these agents as well as other ions are in progress.

Cs^{137} Cores

Eight cores of varied length were fed water spiked with 1×10^6 cpm/l of Cs^{137} applied as $CsNO_3$. In addition one core received a spike of 10×10^6 cpm/l. Both distilled and tap water were used as diluents to bring the spikes to the required concentration.

Swope (7) has reported that cesium is not held tightly by the resin, Nalcite HCR. However, she points out further that there is a difference among the various synthetic ion exchangers in their ability to retain cesium. That

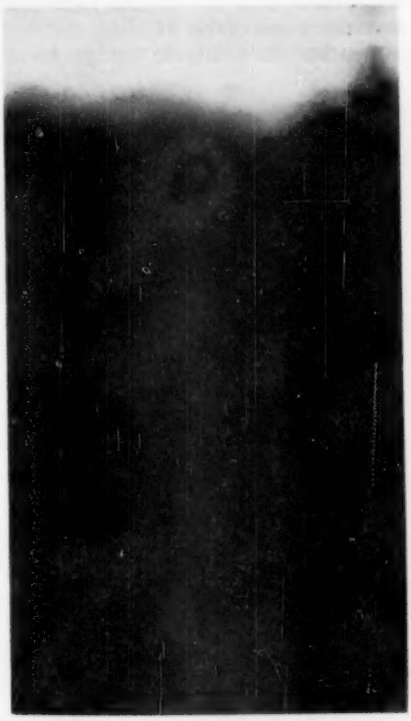

FIGURE 3.—Autoradiograph of tuff core—Cs^{137} studies.

there is a great difference between synthetic ion exchangers and soils has been borne out by the investigations reported here. It was found that cesium was bound very tightly by the tuff with little regard for other ions present in tap water. The lowest percentage retention was 99.6 and the highest was 99.99 +. Autoradiographs (Figure 3) support the above observations and indicate the cesium to be concentrated in the upper 1 in. of core volume. The amount of water passed through the core varied up to 330 l which represents some 1,300 in. of water added over a period of nearly six months. There was no apparent difference between the tap and distilled water solutions. Later attempts to dislodge the adsorbed cesium by leaching with solutions of sodium, calcium, magnesium, and carbonic acid were futile and the cesium remained stationary (see Table II).

Another investigation in progress, Project Green Thumb, has yielded some results which are applicable to the present study. Project Green Thumb is primarily a study of the effect of calcium on the adsorption from spiked soils of Sr^{90} and Cs^{137} by plants. When a spike of these two radionuclides was uniformly distributed through 25 sq ft of soil to a depth of 18 in., Sr^{90} was found to leach from the soil and to appear in the seepage from the bottom of the plots. The amount of Sr^{90} leaching from the soil was proportional to the concentration of calcium applied. The observation did not hold true for Cs^{137} which remained evenly distributed within the soil. The Sr^{90} from a mixed spike applied at the surface migrated downward through the soil but the Cs^{137} remained at the point of application. The results are similar to those observed when a mixed spike of Sr^{90} and Cs^{137} was applied to the surface of a tuff core.

TABLE II.—Summary of Tuff Core Study Results

Core	Nuclide	Core Length (in.)	Breakthrough Volume (l)	Total Volume Through (l)	Nuclide Removal (%)
1*	Pu^{239}	7.25	—†	331	96.2
2‡	Pu^{239}	7.00	—†	209	96.1
5*	Pu^{239}	6.25	—†	98	96.0
6‡	Pu^{239}	6.25	—†	99	96.7
3‡	Sr^{90}	5.50	30.0	37§	26.4¶
3A‡	Sr^{90}	7.25	50.0	41§	64.0¶
4‡	Sr^{90}	13.75	—†	23	97.0
4A‡	Sr^{90}	13.00	143	63§	88.0¶
7‡	Sr^{90}	6.25	27	22§	65.0¶
8‡	Sr^{90}	12.50	92	65§	73.0¶
13*	Sr^{90}	12.75	400	98§	88.0¶
19‡	Sr^{90}	9.75	20	29§	80.0¶
22*	Sr^{90}	9.75	—†	198	98.0
11‡	Cs^{137}	6.00	—†	62	99.9
14*	Cs^{137}	12.50	—†	330	99.7
16‡	Cs^{137}	6.80	—†	93	99.6
17‡	Cs^{137}	7.00	—†	98	99.9
18‡	Cs^{137}	7.50	—†	261	99.5
23*	Cs^{137}	10.30	—†	240	99.7

* Distilled-water solvent.
† No breakthrough observed.
‡ Tap-water solvent.
§ Throughput volume after breakthrough.
¶ Removal after breakthrough.

The movement of Cs^{137} was further investigated in the laboratory by passing a solution of Cs^{137} through a column of soil. When the nuclide, in tap water, was fed to the column it accumulated at the surface as was shown by radioautography. A spike applied to the surface of the soil was not moved by a tap water leach but remained as a thin band at the point of application.

Sr^{90} Cores

The investigation of the passage of Sr^{90} * through tuff cores proved to be the most interesting of the three nuclides studied. Sr^{90} is not nearly so tightly bound to the tuff core as plutonium or cesium. Furthermore, percolation through the cores demonstrated a method of separating strontium and yttrium. Something over 90 per cent of the activity coming through the core was due to Sr^{90}.

Seven cores were set up using tap and distilled water as the Sr^{90} solvent. An autoradiograph of a typical core after breakthrough is shown in Figure 4. It will be noted that the strontium has penetrated the full depth of the core. It is also interesting to note the many "hot" spots throughout the core where activity concentrated. This is similar to the phenomenon noted on the autoradiograph for the plutonium core. One other feature to be noted is the density gradation throughout the core indicating a wide variation of ion exchange capacities.

Two typical runs with tap and distilled water are shown in Figure 5. The shape of the curves is quite similar to the typical curves obtained in determining ion exchange capacities by the method of Frysinger and Thomas (8). The first sharp break in the curve is considered to be the breakthrough point. In these particular cores some 80 l were passed through before an appreciable amount of strontium appeared in the effluent. In the case of the tap-water solvent, after 140 l had been applied the concentration of Sr^{90} in the effluent was approximately the same as in the influent. This volume increased to over 200 l when distilled water was used as the solvent.

The slope of the curve for tap water is greater than for distilled water; however, both curves level off at about the same point. The difference in slopes may be explained on the basis of the competition of elements in tap water and of Sr^{90} for the adsorption sites on the adsorbing surfaces, hence a more rapid saturation of the core when tap water is applied. An explanation might be sought for the continued removal of strontium after the core has apparently been saturated with calcium. It is probable that some small amount of calcium is being replaced by strontium; however, the amount of calcium replaced would be so small as to be undetected by the analytical pro-

FIGURE 4.—Autoradiograph of tuff core—Sr^{90} studies.

* Sr^{90} feed implies an equilibrium mixture of Sr^{90} with its daughter, Y^{90}.

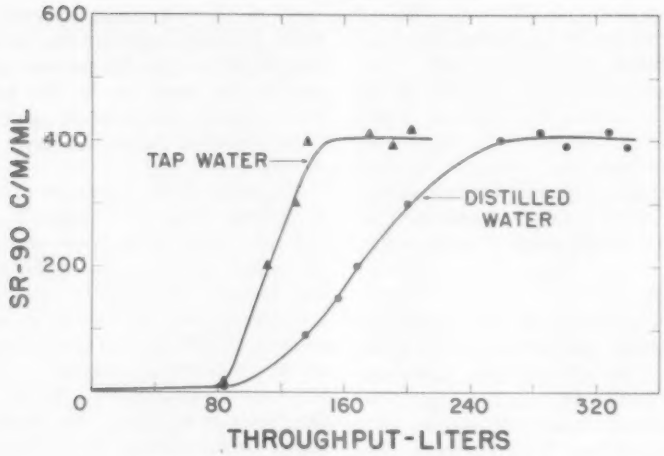

FIGURE 5.—Breakthrough curves for Sr^{90}.

cedures used. It seems reasonable to propose also that within the heterogeneous tuff there exists a wide variety of adsorbents and that some of these might bind the strontium molecule preferentially whereas little or no attraction is exhibited for the calcium molecule. Hence strontium is removed for a period of time after the calcium adsorbing sites have been satisfied. Such a phenomenon is not unknown and is the basis of differential removal of components from biological reaction mixtures by successive treatment with a variety of adsorbing resins. The various synthetic resins show a wide range of preference for different cations so it seems reasonable to assume that the components of tuff could easily demonstrate a similar phenomenon. Unfortunately, there is little, if any, information on ion exchange reactions in extremely low concentrations and much work must yet be done to understand these phenomena.

As noted above, over 90 per cent of the activity in the effluent of the column was due to Sr^{90}. Apparently the relatively high concentration of the divalent ions, calcium and magnesium, does not prevent the adsorption of the trivalent ion, yttrium. The effect of other trivalent ions such as aluminum and iron is being studied.

Mixed Nuclides

In general a waste is a mixture of several nuclides, therefore, the transport of mixed nuclides through tuff cores was investigated. Spikes of both Sr^{90} plus Cs^{137} and Sr^{90} plus Cs^{137} plus Pu^{239} were used as influent at a level of 1,000 cpm/ml each.

One core received a total of 190 l of a Sr^{90}-Cs^{137} spike. Sr^{90} broke through at about 80 l. No Cs^{137} appeared in the effluent after 190 l had passed.

Autoradiographs of the core, Figure 6, indicate the travel of the nuclides. The picture on the left, made with no shielding, reflects the concentration of both Sr^{90} and Cs^{137}. The picture on the right was exposed through 1/16 in. of lead and reflects only the location of Cs^{137}. It will be noted that the Cs^{137} was again concentrated in the top 2 in. of the core while the Sr^{90} was spread throughout.

The core treated with Sr^{90}-Cs^{137}-Pu^{239} mixed spike was 18 in. long. A total of 82 l of spiked solution was passed through. The volume of spiked solution was held low to avoid break-

through in order to obtain a distribution picture of the adsorbed nuclides.

Figure 7 shows the comparison of these radiographs. The picture on the left was made with aluminum foil shielding and reflects the strontium and cesium distribution. The center picture was exposed through lead and reflects the cesium distribution. The picture on the right is a series of photo-micrographs of nuclear track plates placed on the top 3 in. of the core. This type of plate is made by exposing microscope slides coated with photographic emulsion. The alpha particle, because of its relatively large size, does not penetrate the emulsion as is the case with X-rays, gamma rays and beta particles but instead travels along the emulsion leaving a track. A photomicrograph is then taken of the exposure to locate the alpha particle. The magnification of a typical "sunburst" shown in Figure 7 is 400 ×. From Figure 7 it will be noted again that cesium is located at the top, plutonium travels somewhat further, and the strontium penetrated to a depth of nearly 10 in.

Leaching Studies

Early in this investigation it was observed that Sr^{90} in tap water showed a different rate of movement in the core from that observed for the radionuclide in distilled water. In some

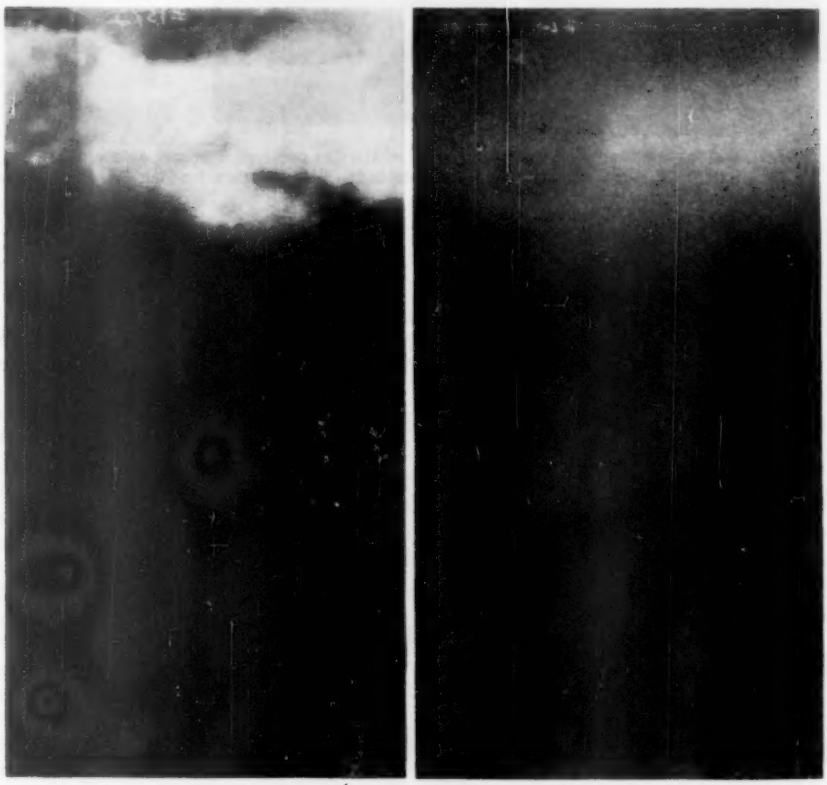

FIGURE 6.—Autoradiographs of tuff core which received a mixed solution of Cs^{137} and Sr^{90}. Picture on left unshielded; picture on right lead shielded.

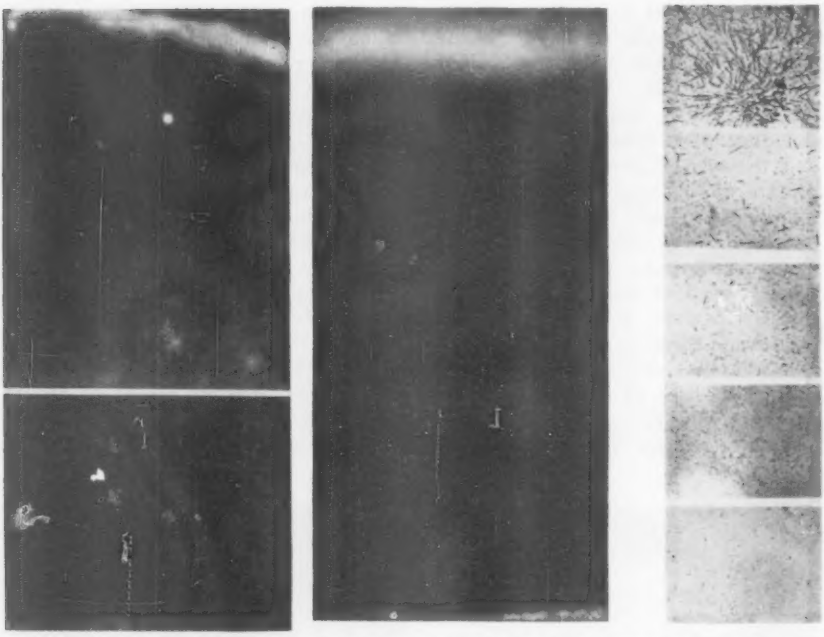

FIGURE 7.—Autoradiographs of tuff core which has received a mixed solution of Pu^{239}, Cs^{137}, and Sr^{90}. Picture on left aluminum shielded; center picture lead shielded. Picture on right is alpha track.

instances there were marked differences in rates of movement. It was theorized that certain elements in the tap water might be competing with the Sr^{90} molecules for position at the site of adsorption. The theory was further investigated by leaching cores which had previously received Sr^{90} up to the point of breakthrough. Referring to Figure 8, it will be noted that the first portion of the curve represents the application of the radionuclide in tap water to the core. This portion is typical of other curves obtained in the study except that it is foreshortened. The maximum level (flat portion) of the curve is followed by a rapid decrease in the release of nuclide as distilled water is applied to the core. This decrease has been observed when other similarly treated cores have been leached with distilled water.

Of interest is the increased amount of Sr^{90} released by a solution of H_2CO_3 prepared by saturation of distilled water with CO_2. It was noted that the released radioactivity was about 95 per cent Sr^{90} as was the case with the adsorption studies. Although H_2CO_3 was applied at a continuous rate to a total of 72 l, a sharp decline occurred in released counts after a small increment of leach solution had passed through the core. A similar pattern has been noted with all leach solutions employed. It is possible that the radionuclide is bound to different tuff components with different binding energies and after the weakly bound Sr^{90} has been released, no further leaching occurs until a more rigorous treatment is employed. Concurrently there is a release of calcium from the core and its concentration peaks at about the same point as the peak concentration of strontium. After peak

release the concentration curves of calcium and radionuclides are parallel. McHenry *et al.* (9) have shown the effect of pH on the adsorption of Sr^{90} by soil. Since the pH of the carbonic acid feed was about 4.4, it is possible that the leaching of tuff core is, in fact, a pH effect, i.e., a hydrogen regeneration of certain ion exchange components.

Leaching with sodium chloride resulted only in a decrease of calcium and strontium in the effluent. It is to be expected from the lyotropic series that sodium would have little effect on the release of ions higher in the series.

The application of magnesium chloride as a leach resulted in a rapid rise and equally rapid fall in the concentration of Sr^{90} released to the effluent. Magnesium would appear to be about as efficient as carbonic acid in releasing Sr^{90}, however, it is more effective in that it releases bound radionuclides that the latter does not release.

Magnesium also releases calcium from the core in comparatively high concentrations. After the peak has been reached the Ca and Sr^{90} concentrations show a parallel decrease.

The application of calcium resulted in little release of radionuclides; in fact the Sr^{90} concentration in the effluent from the core gradually dropped. The magnesium concentration likewise dropped to zero and remained at that level.

A mixed leach of calcium, sodium, and magnesium had no appreciable effect on the release of Sr^{90} from the core. The concentration of magnesium in the effluent rose rapidly to 100 ppm, the applied concentration, and remained at that level. The increased concentration to 150 ppm in the effluent is real but difficult to explain.

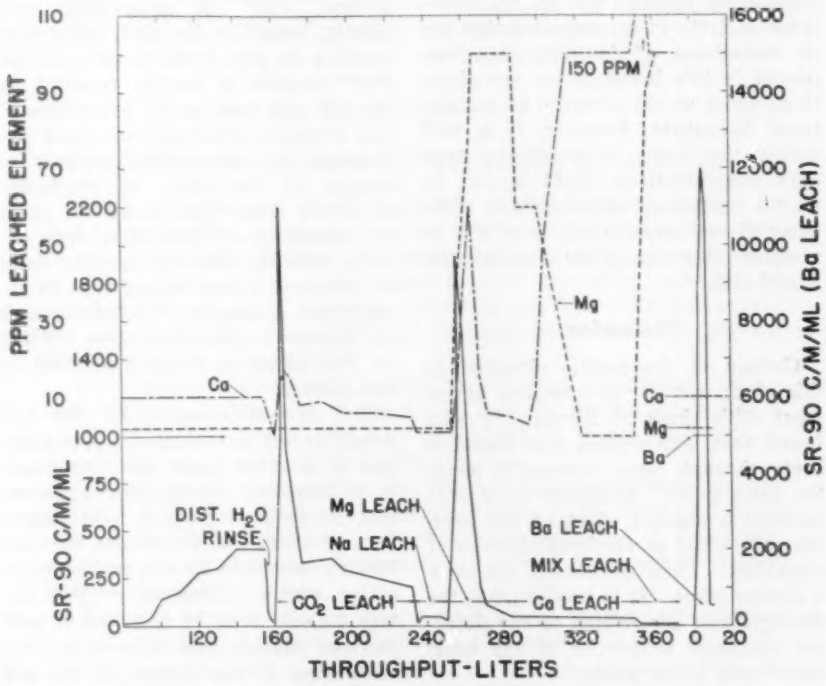

FIGURE 8.—Effects of leach solutions on tuff core—Sr^{90} studies.

Due to its position in the lyotropic series, barium should be extremely efficient in the replacement of Sr^{90} adsorbed on an exchange medium. The application of barium chloride to a core previously receiving Sr^{90} resulted in the release of the radionuclide at above 12,000 cpm/ml (note the different scale for barium leach in Figure 8). This release is about 12 times the concentration of radionuclide applied to the core. Barium also released increased concentrations of magnesium and calcium as would be predicted.

Distilled water was added to rinse the barium from the core. This was followed by a leach solution of magnesium chloride resulting in an extensive release of radionuclide. It was expected the release would occur but at a lower value. The result is not explained by data obtained to date.

The leaching studies to date have shown the important effect of water percolating through soil on the movement of Sr^{90}. It is recognized that the concentrations of leaching ions employed in this investigation are above those which would normally be encountered in nature; however, it is well within the realm of possibility that such concentrations might appear in wastes containing radionuclides. The effect of such concentrations of Sr^{90} in a water table tapped for domestic use is self evident.

Discussion

Certain of the results obtained in this study are not in complete agreement with those of Swope (7) who found that both cesium and hardness broke through resin columns at about the same point. McHenry *et al.* (9) indicate a marked effect of the presence of cesium on the breakthrough of strontium. These studies did not show a similar effect. It is possible that the discrepancies are related to the different exchange properties of the basic adsorbents under study.

Orcutt *et al.* (10) have developed excellent expressions for dispersion and exchange phenomena applicable to radionuclides as they move through soils. Whether nuclides in low concentrations that are amenable to soil disposal will follow accepted physical laws is not known. Thomas (11) has stated that it remains to be proved that elements at concentrations of 10^{-7} M follow classical chemistry or the accepted physical laws of ion exchange. It is possible that a demonstration of the applicability of the mathematical treatment of Orcutt *et al.* (10) to solutions where concentrations of solute approach 10^{-7} M will indicate the nature of their chemistry.

It has been demonstrated that the tuff local to Los Alamos has a rather high capacity for the retention of various nuclides. This is especially notable since this particular material has an ion exchange capacity which is about as low as any to be found in nature. Cs^{137} is apparently very tightly bound to the tuff and resists leaching by any of the common agents. Pu^{239} likewise is readily retained by the tuff and from actual experience at Los Alamos, plutonium in wastes discharged into the ground appear to remain at the point of discharge. However, from what is known about the chemistry of plutonium, it is entirely possible that this nuclide could be released at some future time by inadvertent discharge of solutions such as versene in the same area. Work on this phase is being conducted at Los Alamos.

Sr^{90} is not retained by the tuff nearly so well as cesium and plutonium and it is much more easily released. It is becoming increasingly apparent that its fixation poses a most important problem, and it remains the controlling isotope in the disposal of radioactive wastes. Disposal of this isotope to soils is to be undertaken with extreme caution and only with foreknowledge of the nature of the soil and its capacity for the ions known

to be present in the waste. Because Sr^{90} can be leached by other ions, a disposal area receiving this isotope must be closely guarded so that no other wastes will be discharged which might contain concentrations of ions sufficient to dislodge the already adsorbed nuclide.

Acknowledgment

The authors wish to express appreciation to Julia Marie Wellnitz for the autoradiotography entailed in this paper.

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AMERICAN ACADEMY OF SANITARY ENGINEERS

The recent addition of 100 engineers raised the total number of Diplomates in the American Academy of Sanitary Engineers to 979. Of those previously certified, 555 were qualified through specialization in water supply and wastewater disposal, 198 in public health, 31 in industrial hygiene, 10 in air pollution control, and 5 in radiation hygiene and hazard control. An additional 80 had qualified in the general field of sanitary engineering.

The issuance of certificates bearing the specialty designation, "Sanitary Engineer," has been authorized. Anyone previously issued a certificate showing a specialty will be allowed to exchange it, free of charge, for one inscribed, "Sanitary Engineer."

Officers for the coming year are: Thomas R. Camp, Camp, Dresser and McKee, Boston, Mass., reelected Chairman; R. E. Lawrence, Black and Veatch, Kansas City, Mo., reelected Vice-Chairman; R. S. Rankin, Stamford, Conn., reelected Treasurer and elected Secretary to replace Francis B. Elder.

Reelected members of the Board of Trustees, with terms expiring in 1961, were: W. L. Faith, Raymond J. Faust, J. E. Kiker, Jr., R. S. Rankin, and Clarence I. Sterling, Jr. B. A. Poole replaced Wm. A. Hardenbergh.

PREDACIOUS FUNGUS BEHAVIOR IN ACTIVATED SLUDGE SYSTEMS

By Wm. Bridge Cooke and F. J. Ludzack

Respectively, Mycologist and Chemist, Robert A. Taft Sanitary Engineering Center, USPHS, Cincinnati, Ohio

The efficiency of biological processes in the removal of complex chemicals from water depends at present on the development of suitable microbial populations. In a recent investigation of the persistence of nitriles in water, the functioning of several laboratory activated sludge units was apparently impaired by a predacious fungus, *Zoophagus insidians*. This paper describes the events as observed.

Study Conditions

One activated sludge unit served as a stock tank; four received a feed mixture of settled sewage and nitrile in various proportions. The four test units had been acclimated to a specific nitrile over a period of several weeks using a semi-continuous feed. Two additional activated sludge units, designated as Units 6 and 7, were operated on a fill-and-draw basis for preparation of an activated sludge seed. Each of the seven units had demonstrated the ability to produce a clear, highly stabilized effluent, with suspended solids usually ranging from 2 to 15 mg/l and a BOD of less than 10 mg/l. The nitrile sludges generally required withdrawal of 10 to 30 per cent of the solids per week to maintain a mixed liquor-solids proportion of about 2,000 mg/l. Microscopic observation of the sludges showed a mixed population with variations apparently associated with the particular nitrile feed.

Appearance of Fungus

These performances changed drastically within a few days. Settling characteristics of all units changed at about the same time. The stock unit and Units 6 and 7 showed the most serious changes. Adiponitrile and acrylonitrile units showed intermediate effects and lactonitrile and oxydipropionitrile units were affected least. Effluent suspended solids ranged from 20 to 90 mg/l. Mixed liquor solids were reduced concurrently by as much as 1,000 mg/l in some units within one week.

Superficial examination of units showing the most obvious alteration revealed gray to white filamentous masses similar in appearance to *Sphaerotilus*. Microscopic examination showed the "wild" growth to be present in all seven units but the masses were large enough to be seen readily in only three. The abundance of the feathery growth and the obvious imbalance of the biota in the activated sludge systems coincided with the poor performance and required further work in identification, behavior, and control techniques.

It has long been considered that an activated sludge is maintained in its most favorable condition as long as such predatory organisms as flagellates, ciliates, amoebae, and rotifers are present to control the growth of the bacteria which actively remove, by various degradation processes, the impurities of sewage which are present in solid, colloidal or dissolved states. Microscopic examination of the gray feathery floc showed an interesting type of true fungus and demonstrated immediately the probable source of the trouble. In addition to occurring as

visible white streamers, the fungus forming this floc was found throughout the sludge.

The fungus found in the "sick" activated sludge was a predatory fungus, *Zoophagus insidians*, whose diet consists of rotifers, in this case of the genus *Monostyla*. In the seven activated sludge jars under consideration, the principal predator of the bacterial population was *Monostyla*. In other activated sludge experiments in which sewage from the same source was used, principal organisms included nematodes, stalked ciliates such as *Epistyla*, and other organisms, while *Monostyla* was rare or absent. *Zoophagus* was not evident in these tanks.

The Predacious Fungi

Fungi which possess the predacious habit were known as early as 1852 although it was not realized that they were not ordinary molds until their predacious habit was discovered 75 years ago (1). Dreschler, in the United States, has been interested in this type of fungus since 1934 and Duddington, in England, since 1940. More than a hundred species of predatory fungi have been reported, mainly since 1934. These fungi are of interest, from an economic point of view, principally because of their potential ability to aid in the control of the root diseases of beet and cereal crops which are caused by excessive numbers of parasitic nematodes in the soil.

Zoophagus

The predatory fungus which was devouring *Monostyla* in the activated sludge units being studied is a common species, *Zoophagus insidians* Sommerstorff. It was first observed in

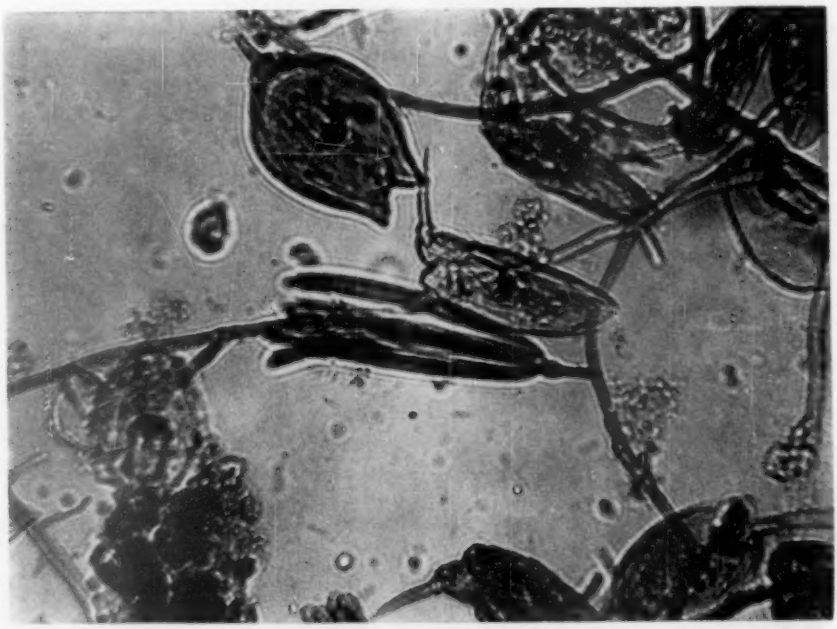

FIGURE 1.—Several hyphae of *Zoophagus insidians* with free and captured individuals of *Monostyla*. A normal individual *Monostyla* appears in upper left; others have been captured and are in various stages of digestion. Note cluster of conidia and a conidiospore in center.

Austria in 1911 (1). The original collection was made in relatively clean water in which the alga *Cladophora* was growing. A species of *Monostyla* was the rotifier upon which it was feeding in the original collection. Since that time it has been reported from Bulgaria, Jugoslavia, France, England, New York, and Maine. Fast-moving species of microscopic animals are too powerful to be held by it. In culture dishes it captures various types of browsing rotifers and, in a short time, can eliminate whole populations.

Action of Predatory Mechanism

The action of the predatory mechanism is interesting. From the time of germination of the gemmae or conidia (Figure 1), spine-like or peg-like capturing organs (Figure 2) are produced along the mycelium. At the tips of these organs a mucilaginous material is secreted. When the browsing rotifer reaches the tip of the capturing organ (possibly stimulated by the discharge from the capturing organ of some as yet unidentified substance or by the presence of bacteria which form the food of the rotifer) the mucilaginous material, which is secreted in sufficient abundance, causes the rotifer to adhere to the capturing organ. From this organ a poorly developed appressorium or haustorium is then formed and from this a mycelial thread grows into the "mouth" of the rotifer and throughout its body (Figure 3). When the protoplasm in the body of the rotifer has been consumed, the cytoplasm in the haustorium appears to be returned to the mycelium. The shell of the rotifer, with whatever fungal tissue is left, is discarded. The capturing organ then is apparently ready to trap another rotifer. Under certain conditions, not observed in this study, zoosporangia are formed within the shell of the rotifer and the resulting zoospores are released through its wall.

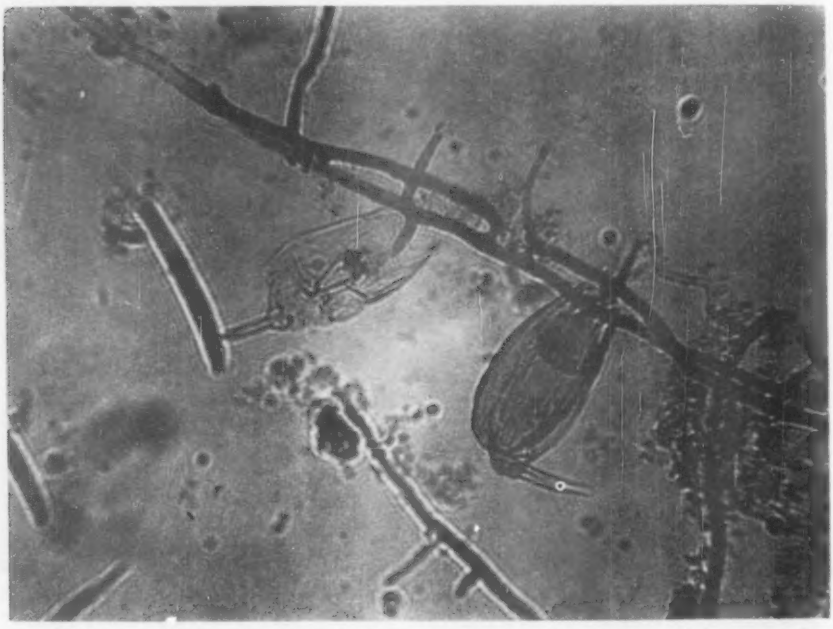

FIGURE 2.—Hyphae *Zoophagus insidians* showing capturing organs. Note captured *Monostyla* and the exhausted shell of a second one.

FIGURE 3.—Two filaments of *Zoophagus insidians*. The one on the left has trapped a *Monostyla* on each of two capturing organs. Mycelium has entered the upper *Monostyla* and has reached its maximum development. Digestion of the lower one is about completed.

Terminology

In previously published reports of this fungus, the terms "conidia" and "gemmae" are used as relating to rarely-produced structures. Since the fungus has been classified by many workers in the Pythiaceae family (and more recently in its own family, the Zoopagaceae) it is traditional to refer to such non-motile hyphal segments which act as reproductive organs as gemmae. However, in the material under consideration, some of the capturing organs develop a cap at their tips on which are produced two to eight elongate conidiospores (Figure 1). These may technically be considered as gemmae since they are non-motile hyphal branches but, because of their abundance in our material and because of their method of production and liberation, they are better considered as conidiospores. From the outset these conidiospores are filled with dense cytoplasm which may be highly granular. They are produced in a crown on the tip of the modified capturing organ and are cylindrical in shape. Apparently their method of discharge, following abstriction, is a mechanical breaking off as a result of maturity and the continuous activity forced upon them in the aeration process. At maturity these spores may reach 100 to 120 μ in length and have a width of 5.5 to 10 μ. Following discharge they may elongate to as much as 170 to 200 μ and become septate before the production of germ tubes on the terminal cells and capturing organs on the other cells. Germination may occur at both ends and at each cell and, as soon as the germ tubes are produced, the capturing organs are formed on the hyphae as well as on the cells of the spore.

Observations

Techniques used in the laboratory, which included both direct observation

and rapidly prepared temporary or semi-permanent mounts, permitted observation of all the pertinent structures with little effort and small loss of material or detail. In direct observation, a drop of sludge containing the organism was placed on a slide, a cover slip was added, and observations were made on the actively moving materials. For temporary mounts, a drop of methylene blue could be added so that cells and some cell contents could be differentially stained. For semi-permanent mounts, a drop of sludge containing fungus material with associated rotifers, or a floc composed of the fungus and accompanying organisms, was placed on a glass slide and a drop of lacto-phenol-acid fuchsin or lacto-phenol-cotton blue was added. A cover glass was placed on the stained portion of the material and excess material was removed by blotting with toweling or other convenient absorbent material. The hyphae of the fungus were stained immediately with no appreciable shrinkage. The hypha which penetrated the body of the rotifer stained more slowly, usually in less than a half hour in acid fuchsin (overnight in cotton blue), and could be seen to good advantage. For semi-permanent storage, the cover glass could be ringed with balsam or other sealing preparations.

In this investigation zoospore formation in the mycelium within the rotifer body has not so far been observed, probably because the growth in the activated sludge was not readily adapted to this method of spore production and because conidiospore formation was adequate for dispersal. During the course of the experiment, with its attendant difficulties, starvation, which is one method of triggering spore production in fungi, was not attempted. Rotifers were captured by the fungus when the substrate included acrylonitrile as well as in sludges containing no nitriles. Conidiospores were produced in two's or three's instead of in clusters numbering up to eight.

Chlorination of Cultures

The long period of sludge acclimitization required for nitrile assimilation made it necessary to save the activated sludge cultures if possible. Since chlorination has been used to control wild growth in activated sludge systems on numerous occasions, it was accordingly tried here. Sodium hypochlorite solution was applied to the mixed liquor, batchwise, in daily doses of 10 mg/l as chlorine for two days. Then the dosage was cut to 5 mg/l for five additional days.

The first two doses of chlorine resulted in a marked reduction of *Zoophagus* and *Monostyla*. The mechanism of reduction was not determined. A small portion of the mycelium floated out with the effluent as scattered fragments. Chlorination inactivated most of the *Monostyla*. *Zoophagus* may have been directly affected by chlorine. A large increase in active copepods occurred following chlorination. Although the predatory fungus virtually disappeared after the first two chlorine applications, five additional chlorine doses were applied mainly to destroy mycelia developing from remaining spores. All units were fed throughout chlorination in the original sequence.

Biological Effects

Chlorination had a marked effect upon other biological forms in the units. Protozoans and other forms of life increased in variety. Copepods appeared in large numbers. Stalked ciliates, flagellates, and nematodes, relatively scarce in the sick sludge, became numerous. Production of oxidized nitrogen fell off about 95 per cent after several days of chlorination. Nitrification had not decreased during the period of wild fungal growth. During the middle of the second week

after chlorination, one unit showed an increase in effluent oxidized nitrogen. The remaining four showed a similar increase four days later. Apparently, chlorination resulted in a major decrease in the population of nitrifying organisms. Their slower regeneration period resulted in a much longer recovery time than for other active organisms.

Sludge Condition

Activated sludge effluents remained in poor condition during the chlorination period. Suspended solids ranged from 20 to 40 mg/l. Mixed liquor solids continued to decrease slowly. Only one to two days were required after discontinuance of chlorination to obtain a clear effluent. Mixed liquor solids began a rapid rise about two weeks after chlorination.

Effect on Nitrile-Consuming Organisms

Nitrile assimilation was undetermined during the period of upset and recovery because of the nitrogen imbalance resulting from sludge destruction. As soon as oxidized nitrogen in the effluent exceeded nitrogen entering in sewage, nitrile nitrogen oxidation became evident, occurring in one test unit during the second week after chlorination and, in the three remaining units, during the third week after chlorination.

It was apparent that nitrile-consuming organisms were not completely destroyed by the upset or by subsequent chlorination. Although up to 11 weeks were required to acclimate a new sludge to nitrile oxidation, all four test units were effectively metabolizing nitriles within three weeks after chlorination.

Conclusions

Chlorine dosage used to correct the wild growth apparently was greater than necessary to accomplish the desired effect. Fewer applications at a lower concentration probably would have destroyed the fungus without seriously affecting nitrifying organisms.

In Units 6 and 7, which were not chlorinated, *Zoophagus* was still evident at a time when the chlorinated units were producing good effluents. The mold was disappearing slowly as if running out of food or because of the large increase in copepods. It is likely that the population balance would have been restored eventually in the test units without treatment but good effluents were obtained two to four weeks earlier in the chlorinated units.

Acknowledgment

Photomicrographs, at × 450, were taken by R. N. Bloomhuff.

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CORRECTION

In the paper, "Interior Photography of Sewers" (THIS JOURNAL, 29, 12, 1398; Dec. 1957), the text description on page 1403 referring to Figure 6 is in error in identifying the pipe in the photograph as being made of vitrified clay. This is an interior photograph of a 36-yr old, 17-in. diameter, concrete pipe.

Stream Pollution

AERATION OF STREAM FLOW AT POWER TURBINES *

By R. H. Scott and T. F. Wisniewski; and
B. F. Lueck and A. J. Wiley

Respectively, Wisconsin Committee on Water Pollution, Madison, Wis.; and Sulphite Pulp Manufacturers' Research League, Appleton, Wis.

This paper reports on a study of aeration of stream flow at power turbines as a part of the cooperative state-industry stream studies in Wisconsin undertaken by the Wisconsin Committee on Water Pollution and the Sulphite Pulp Manufacturers' Research League. The organization of cooperative state-industry stream studies in Wisconsin was reported in This Journal, **29**, 3, 298 (Mar. 1957). The preliminary results of the study by this group on the Lower Fox River were reported in This Journal, **29**, 1, 76 (Jan. 1957). The results of stream purification capacity studies were reported in This Journal, **29**, 9, 1054 (Sept. 1957).

For several years, state-industry cooperative projects concerning stream pollution investigations have been carried out during the summer period. The basic working relationship in such cooperative efforts permits the joint group to embark on considerably larger projects than would be the case if handled by individual group personnel. Past work on cross-section studies of streams (1) (2) provided a workable field testing procedure which adapted itself to examination of the new project for investigation; aeration of stream flow at power turbines.

Initiation of the Study

Interest in the possibility of obtaining significant dissolved oxygen increases in total stream flow by turbine aeration was first stimulated by communications and publications from Wagner (3) in Germany. Wagner's review of work covers virtually all reasonable methods for reaeration of impounded waters and also contains a section concerning advantages to be gained by admitting air to power turbines. These data encouraged the development of a joint project to investigate this possible stream improvement procedure.

At about the same time Wagner's work came to the attention of the state-industry study group, there was consulting engineer † interest in this project as the result of turbine-venting experience in connection with the operation of hydroelectric plants in Wisconsin. Such venting was then intended to reduce cavitation and vibration in the turbine. The two approaches, which were different in intent, none-the-less had a somewhat similar basic application in the sense that turbine-venting procedure was an

* Presented at the 13th Purdue Industrial Wastes Conf., Purdue University; Lafayette, Ind.; May 5–7, 1958; under the title "Cooperative State-Industry Stream Studies in Wisconsin. IV. Aeration of Stream Flow at Power Turbines."

† Bernhard Lueders, Baraboo, Wis.

established practice in Wisconsin and work in Germany indicated certain stream benefits which could be derived by turbine aeration.

The third factor which contributed to interest in this study was the desire of a paper manufacturing plant * to obtain improved stream reaeration over that furnished by compressed air and carborundum diffusers (4). Diffusion facilities had been installed at Pixley Dam on the Flambeau River below Park Falls in 1943 to increase the dissolved oxygen of the stream. The paper company became interested in the possibility of turbine aeration in the hope of improving the oxygen gain and also simplifying the rather elaborate and cumbersome installation employed for air diffusion. Thus, four interested parties united in the same effort; the paper company furnished the facilities for the test; the industry consultant furnished the engineering study from the power-plant standpoint; and the Wisconsin Committee on Water Pollution and the Sulphite Pulp Manufacturers' Research League furnished the testing procedures involving physical and chemical field work necessary for evaluation of the advantages which such an aeration procedure might present.

River Conditions

A brief description of the flow pattern of the river and the air vent installation may be helpful in gaining an understanding of the conditions which had to be met to obtain any reasonable advantage from this method of stream aeration.

The Flambeau River receives no known man-made wastes above Park Falls. The river flow is controlled principally by release from the Flambeau reservoir. The drainage basin at the reservoir outlet is 666 sq miles, while at Park Falls the basin measures 720 sq miles. The reservoir outlet produces a controlled release of at least 609 cfs, 50 per cent of the time, and at least 150 cfs, 95 per cent of the time.

At Park Falls, wastes from a sulfite pulp mill and paper mill, as well as treated sewage effluent, reach the stream. The strong spent sulfite liquor is either employed as roadbinder or disposed of by hauling for land disposal. Pulp-washing wastes are sprayed on an extensive area of bark fill, and leach to the stream. Normal paper-mill wastes are also discharged to the stream. All wastes, including treated sewage effluent, reach the stream just below Mill Dam at Park Falls, the first dam below the reservoir.

Wastes discharged at this point almost immediately enter the flowage area formed by Lower Dam. Some added holding time is thus provided and the dissolved oxygen decreases. After discharge through Lower Dam turbines, the stream flows more rapidly for about a mile before entering Pixley Dam flowage, an extensive body of water providing considerable holding time. Dissolved oxygen in the stream continues to drop through the flowage area and reaches critical levels at Pixley Dam. Discharge from Pixley turbines enters Crowley Dam flowage almost immediately and this body provides further time for waste decomposition. Below Crowley Dam the river flow is more rapid and the stream is used for recreational purposes, including fishing and canoeing. The objective, in considering earlier compressed air aeration at Pixley Dam, was to improve this section of stream below Crowley Dam down to Oxbo, a resort area located about 25 stream miles below Park Falls. The critical dissolved oxygen conditions developed at the Pixley Dam outlet, seven stream miles and two flowage areas below Park Falls, and made this accessible point the likely location for aeration facilities.

* The Flambeau Paper Division of the Kansas City Star Company, Park Falls, Wis.

Air Admission

Pixley Dam has three turbines, two large units and one smaller unit, which were originally installed when the present power plant site was used as a groundwood pulp mill in the 1920's. These units are designated as Turbines 5, 6, and 7. All have been equipped to introduce air into the flow. However, only Turbines 5 and 6 were employed during the experimental work. The smaller unit, Turbine 7, was not used.

Venting the double-runner, horizontal turbines at Pixley Dam was accomplished after study of possible points of inlet in relation to the rotational component of water in the draft tube. Originally, one set of two vents was installed on each turbine and formed the basis for test work in June. By July, the second set of double inlets had been installed on Turbine 5 and comparison of the efficiency of oxygen gain using the two venting positions was thus possible. All air admission was made into the annular space between the runner ring and the conically shaped part of the turbine draft chest which surrounds the runner ring. The vacuum at the point of venting, without air admission, varied in a range of 10.7 to 11.55 in. of mercury throughout the range of gate openings used in the test. Following the installation of the inlet ports, the valves controlling the rate of air inlet were calibrated at several settings so that the amount of air flowing to the turbine was known for the several test conditions employed.

Sampling

With the water of the upstream reservoir at a low level, it was possible to regulate the flow to the turbines at any desired rate. Samples taken at the upstream station (Station A) were primarily grab samples at the 0.2 and 0.8 depth. Generally, three samples were taken at each level; their location being governed by the choice of turbine used for a given test procedure. All composites made from this headrace station were on a straight volume-for-volume basis. The downstream station (Station B) was traversed by a tag line which was divided into 12 equal sections. The stream was gaged at this point, making use of 12 verticals for velocity measurements. The samples taken at this downstream station were obtained from both the 0.2 and 0.8 depths at the odd-numbered verticals. All samples were taken by a Kemmerer sampler. The dissolved oxygen was fixed in the field, and BOD samples were placed in an ice vat for cooling to prevent loss of dissolved oxygen.

Operating Procedure

The standard operating procedure employed in the course of the survey consisted usually of completion of a "base run" at a given gate opening on a specific turbine; this value in oxygen gain or loss establishing conditions existing without air admission. Immediately following completion of this survey procedure, without change in gate opening, the air inlet valves were opened to admit air to the turbines. The valve settings used were previously calibrated to determine the amount of air flowing into the draft chest. As the point of cross sectioning at the downstream station was approximately 1,000 ft below the dam, a minimum period of 1 hr was devoted to clearing the tail water and downstream area of unaerated water following the start of air admission and prior to repeating the survey procedure to determine the dissolved oxygen gain. The survey completed in June was devoted to examining the reaeration characteristics of Turbine 6 at different gate openings and using several rates of air admission. The work completed in July duplicated some of the June tests on Turbine 6 but for the last two days of the survey, only Turbine 5 was employed.

TABLE I.—Power Turbine Aeration Study Results, Flambeau River, Pixley Dam, June 1957

Run No.	Sta.	Date (June)	Flow (cfs)	Turbine (No.)	Gate Opening (%)	Water Temp. (°C)	pH (Avg.)	5-Day BOD 20°C (ppm)	k_{20}	Phenols* (ppm)	Susp. Solids		Dissolved Oxygen						Power (kw)	Gain or Loss in Lb Oxygen Exchange per Day			Lb O_2 Exchange per Kwh Lost
											Total (ppm)	Fixed (ppm)	ppm	Saturation (%)	Into Turbine (lb/sec)	Into Water (ppm)	Change (ppm)	Absorp. Efficiency (%)		Total Measured	Gross	Gross per 1000 cfs	
1	A	4	628	5–6	Normal operation	18.2	6.5	5.5	0.071	—	5.1	2.3	3.46	36	0	0	—	—	—	—	—	—	—
	B	4				19.2	6.7	5.1	0.093	25.8	4.8	1.9	3.39	36	—	—	−0.07	—	—	−237	—	—	—
2	A	5	487	6	99	18.2	6.7	6.7	0.111	27.4	5.0	2.2	3.01	31	0	0	—	—	607	—	—	—	—
	B	5				18.0	6.5	5.8	0.119	—	—	—	2.97	30	—	—	−0.04	—	—	−105	—	—	—
3	A	5	486	6	99	19.8	—	6.7	—	—	—	—	3.27	35	.088	2.90	—	—	570	—	—	—	—
	B	5				19.0	6.5	5.8	0.105	22.8	—	—	3.43	36	—	—	+0.16	5.5	—	+420	+525	+1081	+0.593
4	A	5	465	6	99	21.0	—	6.8	—	—	—	—	3.65	40	.088	3.03	—	—	570	—	—	—	—
	B	5				19.0	6.5	6.2	0.117	—	—	—	3.58	38	—	—	−0.07	—	—	−176	−71	−153	−0.079
5	A	6	410	6	80	18.7	6.6	7.8	0.141	33.3	4.2	1.2	3.50	37	0	0	—	—	463	—	—	—	—
	B	6				19.0	6.6	7.5	0.117	—	—	—	3.12	33	—	—	−0.38	—	—	−841	—	—	—
6	A	6	379	6	80	20.4	6.6	8.3	—	—	—	—	3.71	40	.077	3.27	—	—	442	—	—	—	—
	B	6				20.0	6.6	7.8	0.165	—	—	—	4.15	45	—	—	+0.44	13.5	—	+900	+1741	+4596	+3.45
7	A	6	388	6	80	20.6	6.6	8.2	—	—	—	—	3.93	43	.077	3.19	—	—	442	—	—	—	—
	B	6				20.0	6.7	7.4	0.161	—	—	—	4.20	45	—	—	+0.27	8.5	—	+566	+1407	+3630	+2.79
8	A	7	296	6	60	18.4	6.6	8.0	0.172	27.8	4.2	1.4	2.63	27	0	0	—	—	236	—	—	—	—
	B	7				19.0	6.6	7.8	0.167	—	—	—	2.75	29	—	—	+0.12	—	—	+192	—	—	—
9	A	7	288	6	60	21.6	6.7	7.1	—	—	—	—	3.20	35	.088	4.92	—	—	223	—	—	—	—
	B	7				21.0	6.6	6.7	0.160	—	—	—	4.09	45	—	—	+0.89	18.1	—	+1384	+1192	+4816	+3.83

* Folin-Denis method.

Results

Recording of Data

The accumulated data from the project have been published (5) and the results which were obtained for the separate test conditions are summarized in Tables I and II. Table I covers the information obtained from the tests conducted in June at an incoming dissolved oxygen level of approximately 3.5 ppm. Table II covers the results obtained from test procedures conducted in July at an incoming dissolved oxygen level of less than 1 ppm. All chemical and physical data derived from the original data, as averages or totals, are shown in these tables. Information is also given regarding rate of air admission, calculated absorption efficiency, power loss data, and calculated values of oxygen exchange under the various test conditions employed.

The additional determinations covering 5-day BOD, oxidation rates, Folin-Denis phenol values, and suspended solids were completed on all runs where such information appeared desirable, or used to determine the consistency of conditions during the course of the two individual survey periods. The fact that Pixley Dam is located at a point below two flowage areas, allowing ample opportunity for equalization of waste load, tended to create quite uniform conditions in the stream at this location.

Tables I and II summarize and condense large amounts of data showing the several physical, chemical, and biochemical conditions existing at the points of measurement. In addition to the analyses shown, certain gas analyses of the air escaping in the tail race permits general conclusions to be drawn from this information. Run 19 in July was made using the old diffused aeration system only and serves as an efficiency test against the turbine aeration method of air diffusion.

Factors Affecting Oxygen Balance

There appears to be little doubt that the dissolved oxygen of the stream may be increased by turbine aeration, the degree of increase varying with conditions which are dependent upon upstream dissolved oxygen and also the rate of air admission. This easily measurable gain is the principal asset of the procedure and adds to the purification capacity of the stream. In addition to oxygen gain there is evidence, from these data and from information in Wagner's work, that hydro-plants may actually remove dissolved oxygen from the stream when turbines are not vented. The data are incomplete at present in this regard and further investigations are planned. However, in four out of six unvented runs the dissolved oxygen assets of the stream were reduced upon passage of the stream flow through the unvented turbine. If, in addition to a measurable increase in dissolved oxygen, this DO loss is also cancelled, the dissolved oxygen balance of the river receives this added gain in assets. No speculation is offered on the position this feature of dissolved oxygen decrease may occupy on unpolluted watercourses. However, it is readily apparent that, where such de-aeration effect may manifest itself on heavily loaded streams, the disadvantage of quiescent impoundments is further aggravated by this subtraction of a portion of the stream oxygen.

The third factor in turbine aeration affecting the oxygen balance of the stream involves the small decrease in BOD that appears upon consideration of the data in Tables I and II regardless of turbine venting. The 5-day BOD work, summarized in Table I, is an average of individual samples and shows an added advantage in BOD reduction for turbine venting. The 5-day BOD data, shown for separate test runs in Table II, are single values for composites of each station

TABLE II.—Power Turbine Aeration Study Results, Flambeau River, Pixley Dam, July 1957

Run No.	Sta.	Date (July)	Flow (cfs)	Turbine (No.)	Gate Opening (%)	Water Temp. (°C)	pH (Avg.)	5-Day BOD 20°C (ppm)	k_{20}	Phenols[a] (ppm)	Susp. Solids		Dissolved Oxygen						Power (kw)	Gain or Loss in Lb Oxygen Exchange per Day			Lb O_2 Exchange per Kwh Lost
											Total (ppm)	Fixed (ppm)	ppm	Saturation (%)	Into Turbine (lb/sec)	Into Water (ppm)	Change (ppm)	Absorp. Efficiency (%)		Total Measured	Gross	Gross per 1000 cfs	
10	A	23	397	6	80	25.0	6.8	5.0	0.053	21.1	4.2	0.0	0.13	1	0	0	—	—	460	—	—	—	—
	B	23				25.0	6.9	3.7	0.067	22.2	4.2	0.4	0.27	3	—	—	+0.14	—	—	+300	—	—	—
11	A	23	394	6	80	26.3	6.9	5.1	0.066	21.1	—	—	0.67	7	.079	3.16	—	—	437	—	—	—	—
	B	23				26.0	6.9	4.1	0.081	20.5	—	—	1.43	17	—	—	+0.76	24.1	—	+1616	+1316	+3342	+2.38
12	A	23	394	6	80	27.1	6.9	4.1	0.087	18.3	—	—	1.17	14	.088	3.59	—	—	435	—	—	—	—
	B	23				26.5	6.9	4.2	0.072	20.0	—	—	1.70	20	—	—	+0.53	14.8	—	+1127	+827	+2100	+1.50
13	A	24	660	5–6	75.5–76	24.5	6.8	5.0	0.082	20.5	4.6	0.6	0.43	5	.234[b]	5.69	—	—	751[e]	—	—	—	—
	B	24				24.5	7.0	3.3	0.064	17.8	—	—	1.94	23	—	—	+1.51	26.5	—	+5381	—	—	—
14	A	24	434	5	80	25.2	7.0	3.5	0.089	18.3	—	—	0.39	4	.073[d]	2.71	—	—	499	—	—	—	—
	B	24				25.0	6.9	4.8	0.063	18.3	—	—	1.17	13	—	—	+0.78	28.8	—	+1827	+2358	+5423	+3.50
15	A	24	434	5	80	25.3	6.9	4.8	0.117	18.9	4.6	0.8	0.23	2	.073[e]	2.71	—	—	493	—	—	—	—
	B	24				25.0	6.9	4.3	0.097	18.3	—	—	1.24	14	—	—	+1.01	37.3	—	+2366	+2897	+6923	+3.58
16	A	24	417	5	80	24.4	7.0	5.5	0.109	22.2	4.2	0.4	0.55	6	.177[b]	6.78	—	—	481	—	—	—	—
	B	24				24.3	6.9	4.5	0.103	21.6	—	—	2.12	25	—	—	+1.57	23.2	—	+3534	+4065	+9471	+3.66
17	A	25	427	5	80	24.8	7.0	4.9	0.111	22.2	—	—	0.56	6	.103[d]	3.86	—	—	504	—	—	—	—
	B	25				25.0	7.0	4.9	0.107	20.0	—	—	1.50	18	—	—	+0.94	24.4	—	+2166	+2697	+6283	+4.87
18	A	25	428	5	80	25.1	6.9	5.5	0.106	21.1	4.8	0.8	0.69	7	0	0	—	—	527	—	—	—	—
	B	25				25.0	7.0	5.2	0.116	21.1	—	—	0.48	5	—	—	−0.23	—	—	−531	—	—	—
19	A	25	428	5	80	24.8	6.9	5.3	0.103	21.1	—	—	0.79	8	Compressor only		—	—	59[f]	—	—	—	—
	B	25				25.0	7.0	5.0	0.114	20.5	—	—	0.98	11			+0.19	?	—	+439	+439	+923	+0.31

[a] Folin-Denis method.
[b] Old and new vents.
[c] 824 kw unvented.
[d] New vents.
[e] Old vents.
[f] Average power consumption per hour.

made up from separate samples, in proportion to the flow in the section, and no averages are available. In this case, the average BOD reduction unvented exceeds the vented reduction. It is not assumed that any biochemical reaction takes place in this connection, but rather that either a direct chemical oxidation is provided or that volatile gases are removed under vacuum in the draft chest or washed out during aeration. Additional test work may well show that turbine venting, under some conditions of incoming dissolved oxygen and state of oxidation of added waste, is capable of decreasing the 5-day BOD of stream waters.

Conclusions

Certain general or specific statements may be made which are in the nature of conclusions drawn from the results obtained:

1. The admission of air to a turbine for the purpose of introducing oxygen into the water presented no serious installation or operational difficulties.
2. The amount of oxygen absorbed by the water in passing through the turbine with air admitted seemed principally dependent on the DO saturation level of the water, and on the amount of air admitted.
3. By introducing air into the housing of the turbine, an increase of 0.16 to 1.57 ppm DO, or a gross gain of 525 to 9,471 lb of oxygen per day per 1,000 cfs, was obtained depending on test conditions. The maximum oxygen absorption efficiency amounted to 37.3 per cent.
4. Introducing air into the turbine resulted in a loss in power production. The greatest gross dissolved oxygen gain per kilowatt hour lost amounted to 4.87 lb.
5. The waters passing through a turbine, when air was not being admitted, sometimes lost a portion of the dissolved oxygen. This may be due to cavitation in the turbine runner. If turbine venting eliminates this loss this may well be an added advantage for the process.
6. The data indicated that, when stream waters passing through the turbine contain wastes in an advanced stage of decomposition, a slight decrease in BOD is obtained.
7. Analyses of air escaping from the tail race, sampled during aeration, indicated the presence of combustible gases and a decrease in the oxygen content.
8. Stream aeration by means of turbine venting was superior to aeration by compressor and air diffusion through tubes and plates.

Costs

Air Retention

The cost of any such process will be of first concern to those responsible for installation of venting means and operation of the aeration facilities. The physical installation is basically simple, involving only piped vents properly placed below the runner. However, an engineering study to determine the most advantageous position about the circumference of the runner ring is also indicated, so that the maximum air retention time in the draft tube and tail race may be realized. Coupled with the factor of retention time is the factor of air bubble size. It is evident that the air-water inter-face area is relatively small when large bubbles are created, as compared to that which results from the employment of small effervescent type bubble distribution of air. The latter may be gained by the proper location of the vents to utilize the shearing action of water passing through the runner and into the draft chest. The effort to obtain small bubble size and maximum air retention time, even though involving the expense of several venting locations, may well provide increased oxygen exchange efficiency to such an extent as

to make the added initial expense appear negligible.

Power Loss

In addition to reasonable installation costs, a power loss is sustained which can be figured as an operational cost. The power developed under different test conditions is shown in Tables I and II. The measured and gross oxygen gains have been calculated from the basic data, and the pounds oxygen gain per indicated kilowatt hours lost appears in the righthand column. Basically, these values may be used as a guide to the most efficient operation from the power-loss standpoint, even though the oxygen-exchange efficiency may disagree with these results. This value of indicated kilowatt hours lost per pound of dissolved oxygen gain not only decides the best gate opening and air inlet rate, but also may determine the manner used to vent the turbine. The data in Table II show that Run 17 gave the highest oxygen gain per indicated kilowatt hours lost of all runs completed. Yet, Run 15 showed the greatest efficiency in oxygen exchange. The operational cost of the gains represented by Run 17 may be figured making use of a kilowatt hour cost of one cent as amounting to about $5.50 per day, or about $165 for a 30-day month for this turbine. At this cost, the gain amounts to the measured addition of 2,166 lb of dissolved oxygen to the stream per day, or a gross gain of 6,283 lb per 1,000 cfs per day. The least favorable manner of calculating cost at $5.50 per day for addition of 2,166 lb of dissolved oxygen in the stream still makes the method attractive from the standpoint of oxygen gain versus oxygen demand removal at higher efficiency levels.

An added factor which merits consideration in any cost analysis is the fact that the turbine, while vented, does not actually pass as much water as when unvented. This relationship is figured, by those experienced in this field, as representing the actual saving of one-third the measured power loss. The measured loss is a logical result following reduction of the suction head due to air admission. Yet, if less water is passed, the potential of the flow rejected remains for later use. It is thus reasonable to use two-thirds of the recorded power loss figures in calculating the cost, although this has not been done for the data tabulated.

Equipment Depreciation

The third factor involving cost considerations concerns the possibility of future damage which may be done to the turbine. Unless there is assurance that costly equipment is adequately safeguarded from damage, this method fails to meet a basic requirement which would be of great concern to individuals operating hydroelectric plants. Turbine 5, upon which tests were made, was inspected after almost three months of continuous operation at near-maximum air admission rate. No damage or injury to the runner, runner ring, or draft chest was observed. It is the opinion of those versed in turbine design that any admission of air into the draft chest and below the runner blades cannot damage the runner and should have no effect on the draft chest. The admission of air under lower gate openings may actually cushion the draft tube, quiet operation, and, in some cases, improve turbine output.

Pollution Control Philosophies

In the application of this method of turbine aeration for use on polluted streams, a controversy involving the philosophy of "stream treatment" versus "waste treatment" may develop. For many years, those responsible for water pollution control have directed their efforts toward removal of the organic load from the stream. Treatment of the wastes to the degree

necessary to meet stream demands has been the principal point of attack in combating undesirable stream conditions. Little could be done in the stream itself other than to utilize the dilution and purification capacity provided by the watercourse. The variables of stream purification are well known to all who are associated with this field of endeavor. The load is frequently in precarious balance with the purification capacity which involves all the considerations of reaeration rates, variable seasonal flow or dilution available, maximum water temperatures, and deoxygenation rate of the added load. The vagaries of nature continue to complicate the program of pollution control designed for any watercourse or drainage basin. While such a program attempts to consider all factors involved to arrive at the most reasonable maximum degree of waste treatment necessary, two principal limiting conditions may still result in objectionable stream pollution. Whatever safety factor is included in design, it may, at times, be exceeded by the inconsistent conditions developed by variation in flow and water temperature There is also a practical treatment limit, now fairly well established for sewage and many industrial wastes, which means that some of the streams are now overloaded beyond the ability of nature to maintain satisfactory conditions in the watercourse. Increased population, new industry, new industrial processes, and industrial expansion in established plants combine to require additional stream treatment capacity, to cope with the rapidly increasing residual organic load after waste treatment.

The advantages of spill-ways and rapid turbulent flow sections in stream cross-sections are well enough recognized as furnishing desirable stream reaeration and increasing the capacity of the stream for oxidation of the biochemical demand load. While the reaeration gain permitted by such structures and conditions is mostly accidental, in the sense that such fortunate gains from the stream purification standpoint are incidental to the primary purpose in design of dams, spillways, and raceways, the gain exists and is usually recognized. The ready acceptance of such structures providing stream purification advantages incidental to design and function, would seem to indicate that any purposeful effort to accomplish the same objectives in the stream should be as well accepted.

Application of Principles

It is not intended to develop any preponderant amount of evidence in favor of such methods of stream aeration as turbine venting. Its place in the scheme of water pollution control will be established only on the basis of proven merits after all facets of the procedure are determined and evaluated. It is not believed there need be concern that such a procedure will lower the standards for waste treatment and control at the source. All known methods of control and treatment should continue to be applied prior to admission of treated effluents to the stream. However, it is apparent that all means and methods should be considered in order to achieve the desirable safeguard of sufficient stream purification capacity at all times, or to provide an additional safety factor of increased reaeration which may be used when and if needed. Turbine aeration, limited as it will be in application, is only another tool to be used by the stream pollution control engineer as needs dictate.

What are some of the applications for a reaeration method of this type, and what conditions must be met? The first consideration is degree of pollution causing lowering of dissolved oxygen. While these data are incomplete, it might be concluded that the method becomes less efficient when ap-

plied to waters having a dissolved oxygen saturation above 40 per cent. The lower the incoming dissolved oxygen, the higher the efficiency of aeration. Another requirement involves impoundment of waters and operation of hydroelectric facilities. Both do not always exist together. Thus, reservoirs designed strictly for flood control, would not lend themselves to this method of aeration, even though polluted. Another application of the method of aeration might exist at hydroelectric stations developing high heads, the impoundment being of such depth that seasonal stratification occurs. Some deep impoundments, such as exist in the TVA system, develop oxygen deficiency at the bottom. As the installed generating equipment draws principally bottom water, these deep waters are passed downstream without adequate aeration, to the detriment of the downstream river oxygen.

Future Studies

As is usual with a new project, much remains to be learned. The interest taken by others in examining the method has been encouraging and it is hoped that more test data on the procedure may be forthcoming in the future. Other industry plants have conducted experimental work to investigate the application of the method. The Wisconsin cooperating groups plan additional investigations of this procedure during the summer of 1958. Information available indicates that additional work by other groups will also be completed in the state during this summer. As more interest is shown, and additional results become available, the ultimate position of turbine aeration in relation to stream improvement will be established.

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DUES—1959

The time is here for payment of your 1959 Member Association dues. You are urged not to let this action become forgotten in the rush of the holiday season. You are further reminded that if payment is not on record before February, the mailing of SEWAGE AND INDUSTRIAL WASTES ceases with the January issue. Reinstatement is cumbersome and costly and is accompanied by delays. Therefore, please place this item high on your priority list.

If you do not have at hand your Secretary's complete address, refer to page 482a of this issue.

THE OPERATOR'S CORNER

OPERATOR INGENUITY AT THE TACOMA, WASHINGTON, SEWAGE TREATMENT PLANT *

By Lyman Ketcham

Superintendent, Sewer Utility, Department of Public Works, Tacoma, Wash.

In the operation of a treatment plant it is not sufficient merely to run the influent through the plant and disinfect it. The appearance of the plant, the attitude of the employees, the cooperation given the public and other agencies, the plant reports, and all the other many intangible facets that have become an important part of any public utility are of equal importance. This is true because the main purpose of a treatment plant is based upon the aesthetic considerations of the sensibilities of the American people.

The avowed purpose of a treatment plant is to rid the community of the nuisance of polluted waters. However, if the operation is such that the plant is more of a nuisance than the polluted waters it was intended to alleviate, not much improvement has been gained. Polluted waters depreciate property values. However, if a plant is built and operated in such a way that it also depreciates property values, no improvement has been made. It follows, then, that if a treatment plant is worth operating at all, it is worth operating on such a high level that it will be an asset to the community and not a blight.

All of the above intangible values might be placed in a group called "human relations." There are many different factors that enter into the human relations of a plant, but the most important is the attitude and performance of the individual operator.

Human Relations

Importance of the Operator

It is evident that the most important cog in the successful operation of the treatment plant is the operator. During three-fourths of the operating time he alone is in attendance at the plant, because the plant operates 24 hr a day, 7 days per week. The plant cannot be operated by the city fathers from the city hall, nor by the design engineers, nor even by the plant supervisors when they are home nights and weekends. As the taxpayers have about $2 million invested in the Tacoma sewage treatment plant and intercepting sewer system, it follows that it is extremely important that the operator does his job efficiently. The management of the Tacoma treatment plant believes that this efficiency can best be achieved by making the operator want to do his job well, and that this desire to do a good job can best be fostered by observing the following policies:

* Prepared from the 1955 and 1956 operating reports of the City of Tacoma Sewage Treatment Plant, Tacoma, Wash.

1. Make the treatment plant a place where the operator will be proud to work and bring his friends.

2. Treat each man fairly and try to reward him in proportion to what he contributes to plant efficiency.

3. Give each man responsibility commensurate with his capacity and desire to carry it out.

4. Try to maintain high standards of performance, good working conditions, and fair compensation.

It is believed that this policy has paid off in Tacoma by producing a group of operators who are very much interested in their jobs and in learning more about sewage treatment. A group of high-caliber men have been attracted to the plant. Among the personnel are three college graduates, two of whom are professional engineers.

The work at the treatment plant requires a wide field of knowledge and endeavor. When problems occur it is customary to discuss them with the operators. It is the administrative policy to bring out the initiative and abilities of each man. Several inventions and developments in the mechanical and electrical fields have been worked out at the treatment plant. These money-saving suggestions have contributed to plant efficiency.

A report on arc welding done at the plant won national recognition and a fourth prize award from the Lincoln Arc Welding Foundation.

The operators are active in programs and organizations to promote the cause of sewage treatment. They have served on committees and as officers of the various operators' groups. Most of the operators have obtained their certificates of competency as sewage treatment plant operators. This certificate is part of a voluntary certification program of the Washington State Department of Health and the Pacific Northwest Sewage and Industrial Wastes Association. Many of the operators also have their city licenses as stationary engineers.

Plant Organization

When the plant was first operated it was staffed with a skeleton crew of one chief operator and four operators. Additional laborers and technicians were borrowed from other city departments to do maintenance and extra work. From the beginning this arrangement was unsatisfactory. The crews from other departments were not interested in the plant. Many of them resented having to work in a sewage plant. Most of them felt that assignment to the plant was a convenient occasion to loaf, and since the treatment plant supervisors had little control over them, they took advantage of the situation. This arrangement was bad for the morale of the operators because they felt they were working harder than the outsiders and getting paid less.

There were few tools and little maintenance equipment provided at first. Repair work had to be done with tools borrowed from the tool kits of the operators' cars and from other places. Frequently the plant had to be shut down while awaiting the procurement of extra help or equipment. Often there existed the ridiculous situation of having to schedule the operation of a $1.5 million plant to the convenience of a $4,000 truck. Since much of the specialized equipment in the plant was new to the Tacoma area, a great deal of trouble was experienced in getting outside technicians who were qualified to service it.

At the insistence of the chief operator, the plant personnel and equipment were gradually built up to a point where almost all of the maintenance work could be done by the plant staff. Through a process of training and experience the plant personnel has become expert at maintenance of the plant equipment. By doing more of their own work, the plant staff

was able to increase the efficiency of the plant so that unit costs of operation decreased in spite of generally rising costs.

From the beginning of operations, the plant operators have rotated between operation and maintenance work. In November 1952 a chemist was appointed to the staff. In January 1956, the chemist was advanced to the position of operation supervisor and chemist and the chief operator advanced to the position of superintendent of the sewer utility, which included the supervision of sewer maintenance as well as of the treatment plant. A sewage plant lead maintenance man was appointed to supervise the maintenance work.

During the early operation of the plant it was under the administration of the sewer section of the engineering division. In January 1955 the Public Works Department was reorganized and the treatment plant was placed under the administration of the Utility Services Division.

This paper is primarily concerned with the operation of the Tacoma sewage treatment plant during its initial five years. Presented are a number of the operational improvements developed by the skill and ingenuity of the operating personnel.

Historical Background

The sewers built in Tacoma, Wash., from 1880 to 1946 were generally combined sewers laid to the nearest water course.

Streams and swamps were purposely drained into the sewers. As this practice continued, the city waterway and adjacent streams became increasingly polluted.

Early attempts at pollution control met with voter resistance. In 1944 a $3 million sewer bond issue was approved for the construction of trunk sewers, interceptors, and a sewage treatment plant to serve the south side of the city. A sewer section was organized in the city engineering division and extensive investigations were made of such factors as quantity of flow, sewage characteristics, and pollution of waterways. The average dry weather flow was found to be about three times the volume which might normally be expected. This was caused by the drainage of underground streams.

Treatment Plant

A primary sewage treatment plant (Figure 1) with separate sludge digestion and effluent chlorination was constructed in 1950–52 at a cost of

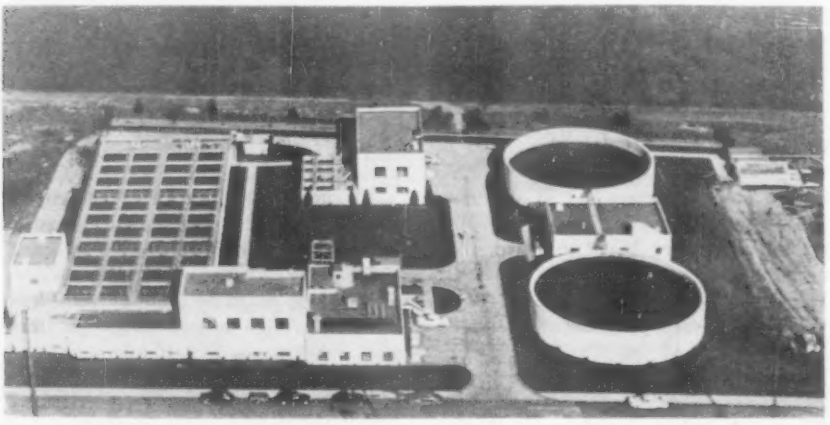


FIGURE 1.—Aerial view of the Tacoma, Wash., sewage treatment plant.

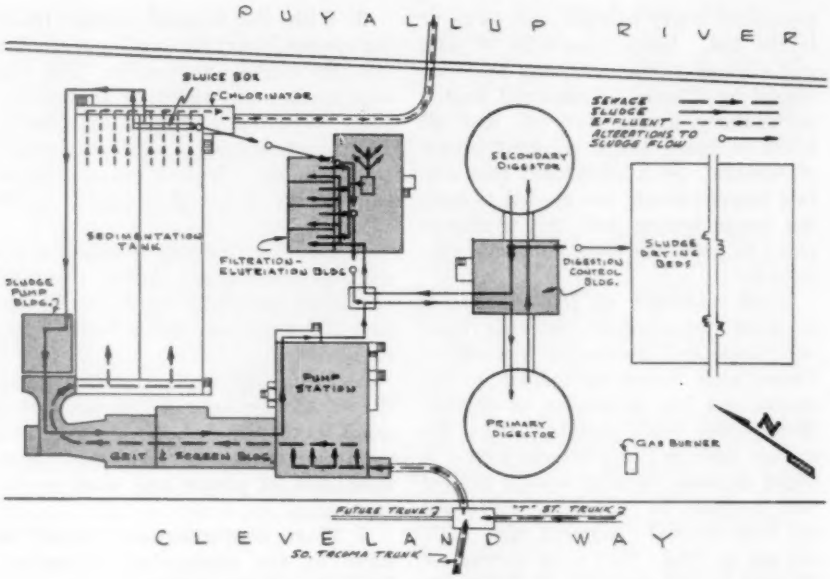


FIGURE 2.—Flow diagram.

$1.5 million. The original design provided for a capacity of 27 mgd using two sedimentation tanks. Lack of funds resulted in the provision of only one-half of this capacity through the construction of one sedimentation tank. A flow diagram of the treatment plant is given in Figure 2.

The flow arrives at the plant through a 48-in. and a 27-in. intercepter. Short flow distances and high infiltration rates result in a dilute sewage, free from offensive odors and high in dissolved oxygen (6 ppm). The sewage is lifted to the head of the plant and flows through the treatment units by gravity. An automatic emergency gate prevents flooding of the plant.

A coarse bar screen, manually cleaned, protects the wet well. The wet well serves as a grit chamber and wet well for the four low lift pumps. Coarse grit is removed from the wet well by a mechanical bucket elevator. A mechanically cleaned bar screen and fine grit channel follow the pumps. The sand and screenings are discharged to a hopper and hauled to the garbage dump.

Dual Parshall flumes measure the sewage flow. Separation of the settleable solids is accomplished in two rectangular tanks (75 ft by 185 ft) which comprise one sedimentation unit. The tanks are equipped with sludge removal mechanisms and pre-aeration facilities. A flash mixer is utilized for chlorine contact.

Two 75-ft diameter digesters handle the sludge. The primary digester has a floating cover and is heated. The secondary tank is open. Sludge can be dewatered on vacuum filters or natural drying beds.

The plant grounds are attractively landscaped and the roads are paved. Considerable money was saved by acquiring trees and shrubs for landscaping free of charge from certain construction projects.

Plant Operation

Tacoma sewage is characterized by extreme dilution, especially during

periods of heavy rainfall such as occur in the fall. Large quantities of sand and silt add to the operating problems caused by dilution. Industrial wastes, particularly grease and oil, and all kinds of trash are a constant source of trouble. It is recognized that certain improvements are needed to both the sewer system and the treatment plant to overcome these abnormal conditions.

Plant operation in 1956 continued to show improvement resulting from experience and mechanical alterations. There were fewer equipment breakdowns and less by-passing of sewage. More solids were removed from the sewage than in the previous year. A slight decrease in total sewage treated was recorded in 1956 when 8,046 mil gal were treated compared with 8,223 mil gal in 1955. This is an average of 22 mgd or 162 per cent of design capacity. The cost of maintenance and operation of the treatment plant was $11.51 per million gallons treated.

During stormy weather plant operation was plagued by sewage dilution, grit, and trash. However, a method was worked out so that by controlling the wet well level the bulk of the grit can be received at convenient times. This helps to avoid accumulations of grit in the intercepter which break loose when least expected.

Operating Problems

The principal operating problems were:

1. The installed grit pumps were designed to handle ¼-in. maximum material. However, the material received included golf balls, peach pits, and gravel up to 2 in. in size. This kept the grit pumps plugged almost constantly.

2. The grit removal system did not take out enough of the fine sand. Most of the material passing a 40-mesh sieve was left in the sludge. This contributed to poor digester operation.

3. With the original sludge transfer system it was impossible to thicken the raw sludge sufficiently. This was due to the fact that the raw sludge lines were too long and the sludge sumps not suitably shaped to produce thick sludge. The large proportion of sand in the sludge also contributed to the problem.

4. The electrical switch gear for the main pumps was not able to withstand the rapid switching called for by the pumping program, and it broke down excessively.

5. The primary digester had insufficient mixing capacity to prevent a scum layer from forming on top. This condition was aggravated by the large quantities of grease and sand in the sludge.

6. There were numerous "bugs" in some of the mechanical equipment. Moreover, it was difficult to get competent outside technical assistance to repair the equipment. This situation was largely caused by the fact that the plant was completed during the Korean War when there was a decided sellers' market in machinery and technicians.

Many experiments were tried to overcome these problems. The history of the treatment plant is largely a report of the continuous battle to overcome them. In many cases temporary expedients were adopted until money for more permanent solutions could be obtained.

Plant Improvements

Bucket Elevator

A number of improvements were made to the bucket elevator grit removal mechanism. This unit was a source of considerable trouble, breaking down every week or two. The elevator had been installed in 1954 in an effort to solve a difficult clogging problem with the wet well grit pumps originally installed.

After considerable study the grit

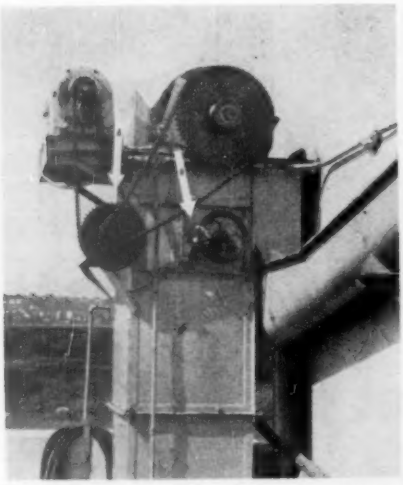


FIGURE 3.—Modified bucket elevator drive gear. Arrow A is a jack shaft; Arrow B is a zero-speed switch.

elevator was modified so that it was practical to operate. Figure 3 shows the modified elevator drive gear. Changes were made as follows:

1. A protective control switch was installed so that when the elevator jams all the conveyors ahead of it automatically stop.
2. The foot bearings, which were the weakest part of the system, were reinforced.
3. The lower sprocket wheels were replaced with traction wheels.

A jack shaft (Arrow A, Figure 3) was installed to slow down the bucket speed which was found to be too fast. A zero-speed switch (Arrow B, Figure 3) was installed to cut off the wet well flights when the shear pin breaks on the bucket drive.

The zero-speed switch was made by plant personnel. It consists of a time-delay switch whose lever arm (painted white, Figure 3) has to be tripped every 30 sec by the finger (also painted white, Figure 3) on the wheel attached to the bucket drive shaft. If the lever arm is not tripped, the power is shut off to the elevator. When the drive shaft stops, because of a broken shear pin, the wheel stops and the white finger fails to trip the white lever arm. This cuts off the power to the flights in the wet well and thus prevents the pile-up of sand at the foot of the elevator.

Skimming Tank

An unusually large amount of grease and oil are received at the plant from the various industries. Although the discharge of these wastes is not permitted by the sewer ordinance, it has been difficult to enforce the code.

It was originally contemplated that these floating wastes would be handled in the digesters. However, they have caused considerable trouble by plugging the sludge lines and forming a scum on the digesters.

A grease separation trap or skimming tank was built from a surplus Navy pontoon tank (Figure 4). The diluted skimmings from the sedimentation tank enter the skimming tank through a large pipe (center arrow, Figure 4). The scum floats and the water runs back to the wet well over an adjustable weir (right arrow, Figure 4). The weir controls the water level in the skimming tank. The grease and skimmings float to the top of the tank and are skimmed off over the apron (left arrow, Figure 4) into a trailer for later disposal by burial.

Sluice Box Degritter

Sand and silt received through the combined sewers constituted one of the most acute problems. The presence of grit reduced the organic content of the sludge and made pumping difficult.

The original grit removal equipment was ineffective in removing the fine material from the raw sewage. After considerable experimentation a flume was developed to remove the sand and silt from the sedimentation tank sludge. It works on a principle simi-

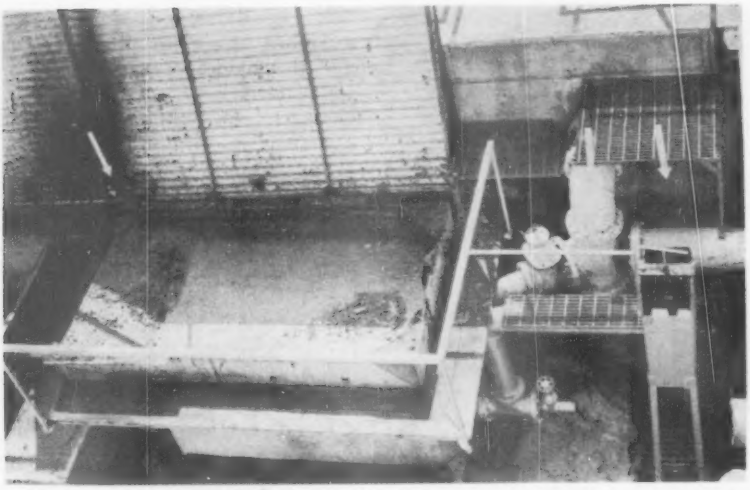


FIGURE 4.—Skimming tank for grease removal.

lar to that of a gold mine sluice box.

Figure 5 is a view of the flume looking up stream; the sludge flow is shut off and the sand is ready for removal. A very good separation of sand from organic material is achieved. Two air lifts (Figure 6) move the sludge from the sedimentation tank hoppers to the sluice box. One unit (Arrow B, Figure 6) is a conventional air lift and the other unit (Arrow A, Figure 6) was made from a surplus hot water tank. The effluent from the flume is controlled by an adjustable weir. A water line with a number of conveniently valved openings can be used to add water to the flow of sludge in order to obtain the proper separation.

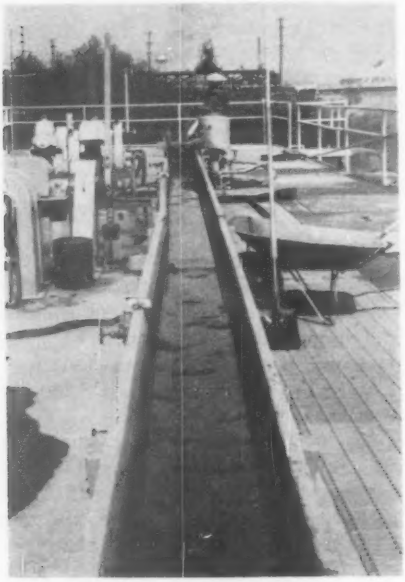


FIGURE 5.—Sluice box degritter.

The sluice-box degritter was constructed by plant personnel for less than $1,000. This included all piping alterations, the air lifts, and the sludge thickening tank alterations. The results have been very satisfactory and the amount of grit removed has been doubled.

Sludge Thickener

The sludge thickener was improvised at the same time the sluice-box degritter was constructed, and was designed to work in conjunction with it. During early operation of the treatment plant it became apparent that raw sludge going to the digesters was too thin. Since the elutriation tanks were not being used, one tank was con-

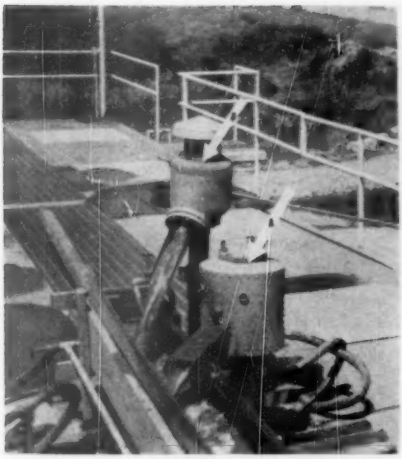


FIGURE 6.—Air lifts for grit and sludge transfer to the degritter.

verted into a sludge thickener in 1956.

All the sludge flows through the sluice box and then through an 8-in. pipe to the sludge thickener (Figure 7). The baffling arrangement in the elutriation tank was changed and a water flushing line was connected to the sludge outlet piping. The excess water flows over a weir and back to the wet well. The thickened sludge is raked by a mechanical collector to the sludge hopper and pumped to the digester. The pumping cycle is scheduled by a time clock. This system performs well on normal sludge and does a good job of improving silty sludge.

Use of Ammonia

Sludge dilution causes trouble because the ammonia nitrogen needed by the methane-producing bacteria is washed out of the sludge in the digester. In turn, the wrong kind of bacteria thrive, the pH drops, and the digester goes sour. Liming is not favored by the operating staff because of the formation of insoluble compounds which inhibit bacteria and have other deleterious effects.

In April 1956 anhydrous ammonia was added to the digester through the recirculating sludge line. The ammonia was supplied in 100-lb cylinders, making the addition of the gas easy. The following beneficial effects have been noted:

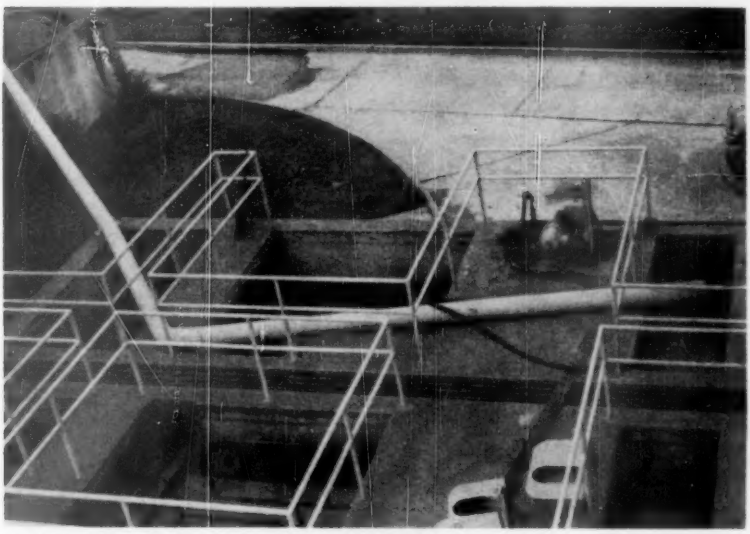


FIGURE 7.—Sludge elutriation tank used to thicken sludge prior to digestion.

1. Ammonia provides food for the methane-producing bacteria.
2. Ammonia neutralizes the digester acids and brings the pH up to a point more conducive to bacterial growth.
3. Ammonia apparently aids in dissolving the scum layer.

Ammonia is relatively cheap in Washington and produces better results than the other additives commonly used. A cylinder or two of ammonia is added whenever the digester appears to be getting sick.

FIGURE 8.—Steam discharge during cleaning of raw sludge lines.

Cleaning Sludge Lines

When the raw sludge lines needed to be cleaned of grease the city sewer crew had to rod out and flush the lines, a straight section at a time. Disconnecting the lines and flushing out the grease created an almost impossible mess and stench.

A method was developed to clean the raw sludge lines by forcing live steam from the heating boilers through the pipes to dissolve the grease. By using steam, the line is opened at only one place outside the building (Figure 8). A better cleaning job is obtained and the mess is easily cleaned up.

Figure 9 shows the cross connection between the steam line (Arrow A) and the sludge line (Arrow C). The gate valve (Arrow B) controls the entry of steam. A check valve to the left of the gate valve prevents sludge from backing up into the steam line.

Sludge Drying

The treatment plant was designed to dewater sludge by vacuum filtra-

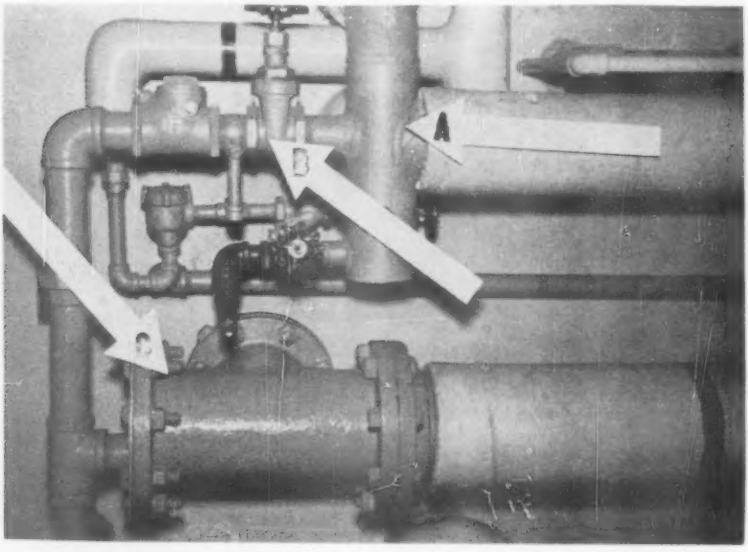


FIGURE 9.—Cross connection for steam cleaning digester sludge lines.

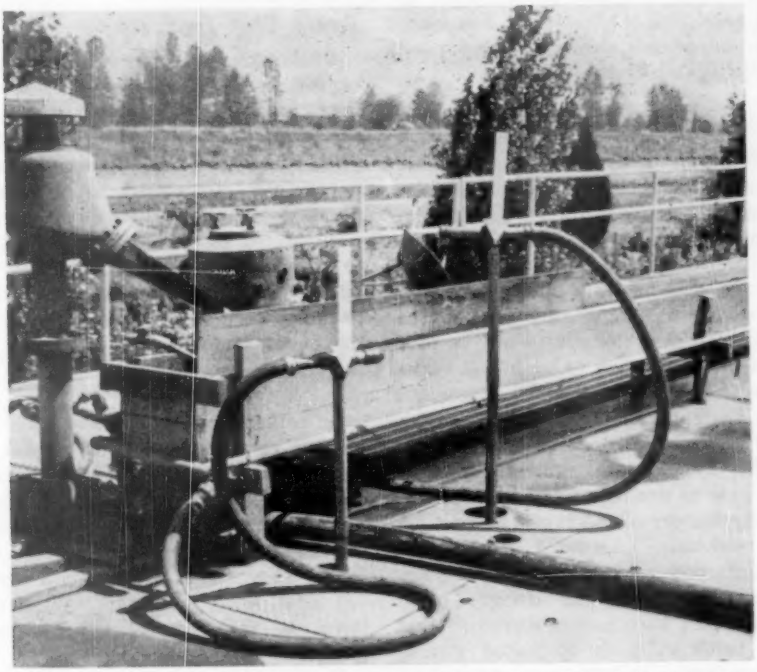


FIGURE 10.—Water lances for loosening sludge and sand in sludge hoppers.

tion. The filters were operated successfully during 1953 and high rates of filter cake production were achieved. In spite of good technical results, the use of filters cost $3 per cubic yard of filter cake produced.

An attempt was made to sell the filter cake as a soil conditioner. The cake was advertised for sale and bids were invited, but none were received. Some experimentation was done on composting the sludge cake and the city garbage. A good organic soil conditioner resulted, although plans to develop it on a commercial basis did not materialize.

A natural sludge drying bed existed on one side of the plant. Accordingly, the practice of pumping digested sludge to the bed was practiced in 1954 and has been continued. The natural sludge beds were gradually improved by plant personnel to take care of increased quantities of sludge. The dried sludge is given free to anyone who will haul it away. In July 1956 a tractor loader was purchased to load the sludge into trucks, thus furnishing a service which makes it attractive for people to get the sludge.

It is estimated that this method of sludge drying and disposal is saving the city approximately $7,000 annually.

Water Lances

Accumulated banks of sludge and sand in the sludge sumps of the sedimentation tank were difficult to pump. A 24-ft probe was used to stir the sumps several times per shift.

A pair of water lances (Figure 10) were made and installed by plant personnel to use water pressure to do the job. Each lance has a pair of horizontal nozzles at the bottom to shoot jets of water into the sumps, breaking

the sand and sludge free. The lances are adjustable from the top, both radially and vertically.

Main Gate Control

Originally a hydraulic system maintained the main gate to the plant either in a fully opened or fully closed position. In case of power failure the gate automatically closed, by-passing the sewage around the plant. A hand valve (lower left Figure 11) was installed so that the gate could be positioned as necessary to control the flow. This, however, nullified the automatic closing feature.

Figure 11 shows the system perfected by plant personnel to position the gate as desired and still retain the safety feature of automatic closing. A solenoid valve (Arrow A, Figure 11), taking power from the emergency lighting system, was designed and made from surplus equipment so that the hand valve is by-passed during power failure and the gate closes automatically.

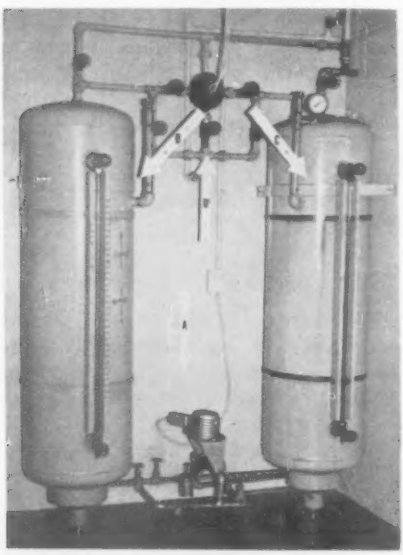


FIGURE 11.—Modified hydraulic system for control of main gate.

Switch Gear Improvement

The switch gear was not sufficiently rugged to automatically operate the main pumps satisfactorily. In January 1957, after considerable study, plant personnel, working with engineers from the equipment company, planned new circuitry. Line starters were added to the main switch gear to permit the frequent switching required of automatic operation. Capacitors were also added to improve the power factor.

Operating Records

A rather complete system of operating records is kept as an aid to good operation. These serve to indicate the effects of various conditions on plant efficiency. Automatic recording meters keep records of the (a) sewage flow, (b) chlorine used, (c) total power input, and (d) power input to each of the main sewage pumps.

Each operator keeps a record in the operator's log book of the events that occur during his shift. He also fills out a daily operational report which contains operating measurements and meter readings. A monthly report which contains sewage characteristics and production data is prepared and sent to the state health department and others.

Plant Maintenance

General Maintenance

Since 1956, a lead maintenance man has been in charge of plant maintenance. This plan has worked well because it has fixed the responsibility for the work. The machine record card system that was instituted in 1955, has been continued and has proved very valuable.

In general, the maintenance procedure is simple. A "bad order" sheet is maintained on the bulletin board. The operations supervisor or any of the plant personnel may list on this

sheet the equipment which is in need of repair or any jobs which, in the opinion of the operator, need to be done. The plant superintendent reviews the list and establishes a priority rating for the different projects. If the solution to a problem is not simple and direct, a conference is held among the staff members concerned and all are invited to express an opinion. The final decision is rendered by the superintendent and the project turned over to the lead maintenance man. Each day the lead maintenance man makes up a daily work sheet, which is a list of the projects to be worked on and the names of the workmen assigned to each project. From the daily work sheets a monthly maintenance report is compiled. Information from this is used to keep the machine record card system up to date.

Operating data for 1955 and 1956 are given in Table I.

TABLE I.—Summary of Operating Data of the Tacoma, Wash., Sewage Treatment Plant for 1955 and 1956

Item	Average 1955	1956
Rainfall (in.)	50.51	40.33
Sewage flow (mgd)	22.53	21.98
By-pass (hr)	297	217.75
Grit (cu ft/mo.)	535	770
Screenings (lb/mo.)	7,954	7,080
Suspended solids:		
Influent (ppm)	111	142
Effluent (ppm)	59	59
Removed (%)	45.5	56
BOD:		
Influent (ppm)	109	134
Effluent (ppm)	64	71
Removed (%)	40.5	41
Grease (lb/mo.)	6,682	8,810
Raw sludge:		
Dry solids pumped (1,000 lb)	2,094	2,980
Solids (%)	4.77	4.4
Ash (%)	37.2	38.3
Digested sludge:		
To sludge bed (1,000 lb)	892.8	1,446.0
Solids (%)	9.6	9.57
Ash (%)	64.8	60.4
Dried sludge (cu yd)	1,275	2,066
Gas production:		
Total (1,000 cu ft)	10,730	16,837
Unit (cu ft/lb vol. matter)	8.2	9.58
Digester temp. (°F)	97	97.6
Digester pH	—	6.7
Alkalinity (ppm)	1,761	1,974
Volatile acids (ppm)	861	535
Chlorine used (tons)	72.2	85.95
Expenses ($):		
Salaries	53,391.66	58,410.31
Operation	38,271.35	34,162.35
Total	91,663.01	92,572.66
Per mil gal treated	11.15	11.51

Preventive Maintenance

Equally as important as the repair program is the preventive maintenance work. This work seeks to service properly each piece of equipment so that it gives a long life of satisfactory service. Lubrication is done periodically on a schedule designed to fit each type of machine. In addition to the lubrication, a schedule is also followed in inspecting and servicing most of the plant equipment. Included in maintenance is a program of materials and equipment testing in an effort to find the best possible product for the money. Tests are also made on different procedures of operation to see which will cause the least wear on the equipment. Many beneficial results have been gained from five years of testing and experimenting.

Considerable interior painting was done in 1956. This included the lower rooms of the administration building, the screening and grit building, and the basement of the digestion control building. The paint used was one that had successfully stood up in a test with five other brands of paint.

Flexible plastic pipe has been used to replace metal pipe and rubber hose in a number of places where tests showed that it would outlast other materials. Oil has been used to replace water in the chlorine heater baths because it does not corrode the tanks. The ordinary electric light bulbs have been replaced with a heavy duty industrial type that gives much longer service.

Acknowledgment

The loyalty and interest of the operating staff are sincerely appreciated. Without their ingenuity and enthusiasm there would be nothing to warrant this paper.

WORK AREA PROTECTION*

By Gordon L. Smith

Division Plant Safety Supervisor, Pacific Telephone and Telegraph Co., Los Angeles, Calif.

Sixty-nine and a half million automobiles are on our nation's highways. For those who need to work on or beneath these roadways this figure takes on a special significance above and beyond its sheer magnitude. No doubt everyone engaged in utility work has openly and silently accused the public of having no regard for our right to use the street. The screech of tires, banging of signs and equipment, and the screams of pain and hysteria all leave an indelible mark.

The proper protection of work areas is one of the most important problems faced today.

The Problem

Statistics show that it is becoming progressively more difficult to work without accident or incident in work areas on the traveled portions of the roadways. Logically so; the continued increase in population, industrial growth, and development of residential areas, resulting in an unprecedented demand for utility service, are factors in the problem. Protection methods, sufficient in years past, are no longer adequate for current needs.

Street surface work for years has

* Presented at the 1958 Annual Meeting, California Sewage and Industrial Wastes Assn.; Stockton, Calif.; April 23–26, 1958.

been planned on an individual job basis. The motoring public has had little knowledge of what to expect upon entering a work area. There has been no uniformity of design or equipment.

Generally all thought was given to the location of the manhole or the length of the trench or excavation. Protective equipment was set up with these considerations as the sole guide. In reality, safety requirements can only be properly determined after full consideration of all conditions. City streets and highways serve a three-fold purpose. In varying degrees, they must bear both pedestrian and vehicular traffic, while beneath the surface and along the sides they furnish an easement for a complicated system of utilities. Each of these purposes must be served in the best possible manner. The utility doing the work cannot disregard the other requirements of the street. Every necessary precaution must be taken for the workmen. Similarly the public must be protected. In addition the work must be performed in a manner which will keep traffic flowing safely with the least inconvenience.

Street surface traffic can be placed in two main categories: congested, slow moving traffic; and high-speed traffic.

Looking at the first of these two categories it is found our present streets handle many times the volume of vehicles they were engineered to carry. For example, an intersection which was laid out at a time when each store faced a hitching rail and twenty teams of horses were not uncommon, now, by actual count, handles 17,000 cars per day. This may not be one of the busiest intersections, but as soon as the street surface is opened it has all the appearances of being one.

In the areas less developed and in those normally referred to as rural, the problems are different but no less hazardous. With 200 to 300 hp on call, and with hard surface roads, the motor vehicle driver often feels he has everything in his favor and soon may be traveling at or near full speed. Seldom does he give thought to workmen who might be just over the next hill. If he does give it a thought, he expects the workmen adequately to protect him and themselves.

The automobile, over the years, has changed from an enjoyable mode of travel to, at times, a homicidal weapon. Additionally, the elevation of the driver above the street surface has been reduced. Today the average eye level of a driver is between four and five feet above the ground. When areas are protected with the presently accepted warning devices 18 to 48 in. high, the driver of the second car in line seldom knows the road is blocked until it is too late.

Unfortunately, the demand for utility services has grown so rapidly that many of the companies have found it necessary to use inadequate warning devices. Others have found it necessary to purchase any device on the market which is purported to be an aid in controlling traffic. The result has been not only unsatisfactory in many instances but has, in general, confused the motoring public on the meaning of warning devices.

There is every reason to believe the degree of congestion and the level of speed traveled will continue. It becomes, therefore, a requirement to accept the hazards involved and conduct operations in a manner that will minimize or eliminate the possibilities of accidents. Work areas must be guarded in a manner which will give the minimum interference to traffic flow by warning the approaching driver in sufficient time to allow him to react to the guidance path without unplanned movements.

Warning Devices

To provide high-level warning for the approaching drivers warning flags and lights have been placed at elevations up to 12 ft. In business areas

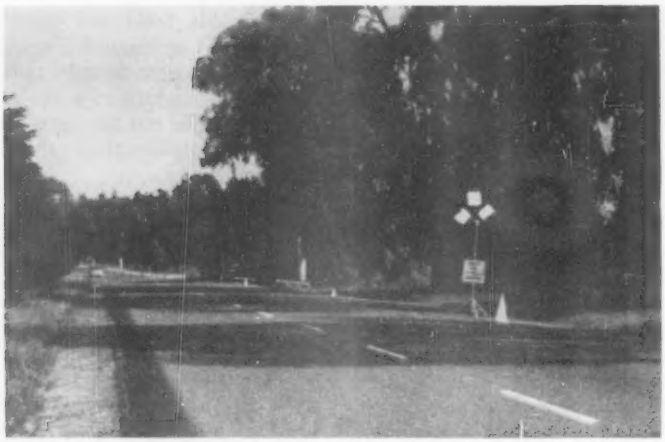


FIGURE 1.—High-level warning device.

this type of warning is visible for two or three blocks and in the country normally up to half a mile (see Figure 1). Units of this type permit the driver to see what is ahead in time to execute the proper maneuver. Adequate warning eliminates the need for split-second decisions and emergency situations. With these emergency situations removed many of the causes of accidents in and around the work areas are eliminated.

The actual location of the high-level warning device relative to the work location is determined after full consideration of traffic volume and speed, plus the characteristics of the terrain and highway. Experience has indicated that the warning should be well in advance of the actual restriction to traffic flow, bearing in mind a vehicle at sixty miles per hour is only thirty seconds away from your work area when it passes a warning device that has been placed half a mile down the road.

It would not appear practicable to establish a set of rules which would specify the distance in feet the warning device should be placed ahead of the work location. This can be determined only at the scene and based on the conditions that prevail. Probably the best determination of accuracy of device placement is to observe the reaction of the drivers as they approach the work area. Adjustment is quite often necessary to secure the maximum protection.

Traffic Guidance

Earlier it was stated that, to have a successful protection program, traffic must be guided around or through the work area with a minimum of interference. The guidance pattern must give immediate visual direction to the driver. The driver has been warned and must now be led into a controlled flow of vehicles. Traffic cones have proved to be adequate for low-level guidance. The actual spacing between cones somewhat parallels the requirements stated previously for the high-level warning device. The speed and rate of flow of the vehicles determine the number of cones required and their spacing. The guidance pattern begins at the first warning device, continues through the work area, and leads the vehicles back to their normal lane of travel. Experience has indicated that cones will generally be properly spaced

if placed one foot apart for each mile per hour traveled by the passing vehicle.

Under certain conditions the use of a 28-in. traffic cone may prove advantageous in emphasizing terminal points of the guidance pattern. However, the standard 18-in. cone will normally prove adequate where properly positioned.

The requirement for night protection varies only in that the warning devices used must be lighted. There may be need to adjust the distances and add to the number of devices used because of reduced visibility. The cone guidance pattern can be lighted by floodlights, individual lighted cone units, or by use of reflectorized material. The work area itself can be lighted by floodlights as an aid to the approaching driver in identifying the reasons for restricted movement. Job requirements and availability of equipment will determine the type of lighting equipment to be used.

Just as an inadequate amount of warning and guidance devices will fail in properly protecting your area, the use of too many flags, cones, signs, and lights can confuse the driver and tend to camouflage the intent of work area protection. Barricades, parked vehicles, and surplus equipment located within the area all play a part in determining the effectiveness of the guidance pattern.

Summary

In placing control devices along the streets and highways, the following general principles should be kept in mind:

1. The driver must have sufficient time and distance in advance of the sign to understand the message, react, and proceed accordingly.
2. The devices must be located at a position visible to all approaching traffic, but not so located as to become a hazard in themselves.
3. Each warning or guidance device should become an integral part of the over-all protection plan and not appear as a haphazard and confusing item to the drivers of approaching vehicles.
4. The use of reflectorized material, lights, flags, cones, etc., can best be determined by thorough surveillance of conditions and traffic reaction at the actual work location.

As a final check, drive through the guidance pattern to determine its effectiveness.

Uniformity of design and use of devices are an essential part of the program to educate the public in recognizing the marking of work areas. Warning and guidance devices must be properly maintained. Damaged, defaced, or dirty signs are ineffective and discredit the agency responsible for them. Accidents, near-misses, congestion and confusion are generally not caused by poor drivers but rather by ineffective or inadequate warning and guidance patterns.

Conclusions

A successful work area protection program must be developed, equipped, and administered on the principles of:

1. Warning not barricading.
2. Guiding not directing.

TIPS AND QUIPS

Safety Alibis *

Alibi	Truth
1. It's all carelessness.	1. I don't know what's causing the trouble.
2. If only management would give me support.	2. It's a comfortable job, if only somebody else would do it for me.
3. Our safety record is good.	3. We don't pay any attention to comparisons and we don't recall many bad ones.
4. We had a lot of freak cases this year.	4. I don't know what the dickens to do.
5. We have a lot of fakers who are goldbricking.	5. I don't like to think of the run-of-the-mill cases that could have been prevented.
6. If I only had a secretary.	6. I hate paper work.
7. They should give me more authority.	7. A policeman can't do the work of a teacher.
8. We have trouble getting them into meetings.	8. The meetings are dull pep talks with some boring statistics thrown in.
9. It's a lot of hot air.	9. The safety man himself lacks conviction.

Filter Media

Several years ago a block of filters at the Minworth Works of the Birmingham Tame and Rea District Drainage Board (Great Britain) was reconstructed. A portion of the bed was divided into four separate sections, each with its own grade of filter media. One part of the bed received 1½-in. new crushed gravel, another, 2½-in. new round gravel, a third, 1½-in. round gravel, and the fourth, 1¼-in. cracked gravel, of which about 34 per cent of the material was classified between ¼ and ¾ in. (the original media). In each of the sections pipes containing perforated canisters filled with media were sunk to the bottom of the bed. At intervals the pipes were withdrawn and the biological accumulation and composition observed.

Analyses of the effluents from the four sections showed that the section with the original media gave best results, in spite of more severe ponding, and the largest media, 2½-in. round gravel, the worst.

* From *National Safety News*, **78**, 1 (July 1958).

Model Plant

Word from Art Reisdorph, Superintendent of the Spokane, Wash., sewage treatment plant, tells of the problems encountered in enlisting personnel to operate the city's new plant. Realizing fully that well-trained operators would be needed, it was a bit unnerving to find qualified personnel unavailable. Reacting to this situation the City together with the State health department and manufacturers' representatives started a training school. Unfortunately there was little opportunity for on-the-job instruction because the new treatment plant was not yet in operation. To overcome this shortcoming, Glen Yake, Superintendent of Water and Sanitary Facilities, suggested the construction of

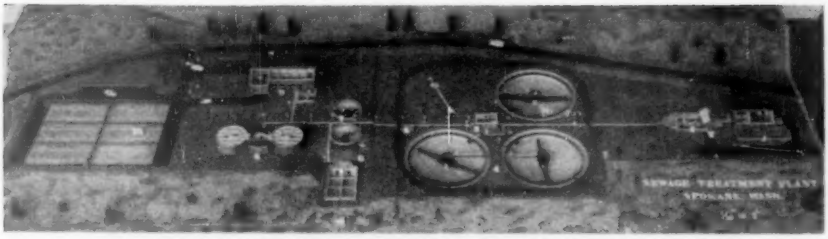


FIGURE 1.—Scale-model of Spokane's sewage treatment plant.

a working model of the plant. Plans for a 1:10-scale model were prepared by Jean Bothel, Engineer, and George Gerdo, Water Department Serviceman, built the replica. The model was built in two elevations so that all plant piping could be studied. The total cost was $3,050 and the total weight, crated, is 460 pounds.

Originally built as a teaching aid the model has since been put on public display at every opportunity. So far, about 275,000 people have seen it.

Figure 1 is the model; Figure 2 is the real thing. On close examination of Figure 2 it looks as though one clarifier is filled with "frayed nerves" and the other with "lost patience."

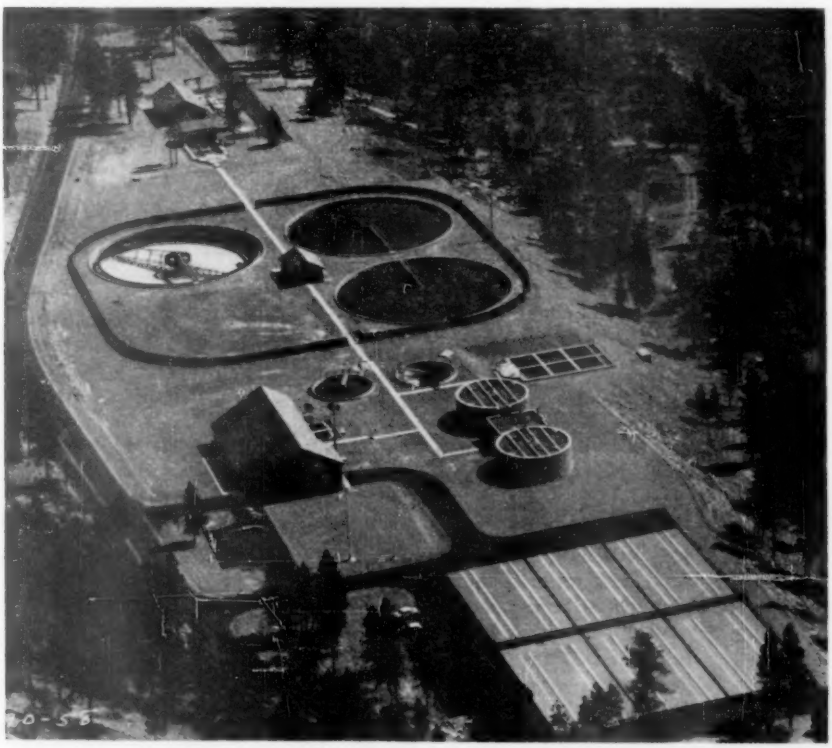


FIGURE 2.—Aerial view of Spokane's sewage treatment plant.

News and Notes

Of Persons and Activities in the Wastewater Field

Klaus Imhoff, son of **Karl Imhoff** of Essen, Germany, has joined the Engineering office of Clyde C. Kennedy, San Francisco.

Raymond W. Hess, longtime consultant to Allied Chemical Company's National Aniline Division in Buffalo, N. Y., died recently. He was a 1957 Bedell Award winner and had been Chairman of the Federation's Industrial Wastes Committee the past several years.

The Texas State Board of Health dedicated a new building in Austin late in November.

Lewis A. Young has been named Secretary-Manager of the Southern Clay Pipe Institute, Inc., newly organized association of clay pipe manufacturers. This group is composed of seven member companies located throughout the southeast quarter of the nation and was created to expand the advertising, public relations, and research activities of vitrified clay pipe on a national basis.

Lt. Col. **Robert G. McCall,** Medical Service Corps, has been appointed Chief of the Sanitary Engineering Section and Assistant Chief of the Medical Service Corps, U. S. Army. He earlier was a Bedell Award winner from the West Virginia Association.

George Bernauer, Sanitary Engineer with the Wisconsin State Board of Health, was killed recently in an automobile accident. He was a past Secretary-Treasurer of Central States Sewage and Industrial Wastes Association.

A. D. Caster, Principal Sewage Disposal Engineer of Cincinnati, Ohio, received the C. W. Nichols Award for his idea to use a television camera in maintenance operations. This is an annual American Public Works Association award.

Henry F. Munroe of Cranston, R. I., has joined Builders-Providence, a Division of B-I-F Industries, Inc., as a Sanitary Engineer.

The Department of Civil Engineering at the University of Illinois recently added **Benjamin B. Ewing** to its staff as Associate Professor of Sanitary Engineering.

R. W. Haywood, Jr. has joined the Washington Suburban Sanitary Commission, Hyattsville, Md., as a Sanitary Engineer.

The **Walter Weyman Co.** recently announced the expansion and removal of their offices to larger quarters in Berkeley, Calif.

Wilbur J. Widmer has been promoted to the rank of Associate Professor at the University of Connecticut.

Sheppard T. Powell, Consulting Engineer of Baltimore, Md., has changed the name of the firm to Sheppard T. Powell and Associates.

Dorr-Oliver, Inc. is now quartered in an ultramodern 120,000-sq ft new building on 20 acres in Stamford, Conn.

William D. Hurst, City Engineer of Winnepeg, Manitoba, has been named as the first Canadian to fill the post of President of the American Public Works Association.

Hersey Manufacturing Co. has opened new Chicago headquarters at 4935 W. Belmont Ave.

Henry W. Taylor, Consulting Engineer of Freeport, N. Y., died recently.

Federation Affairs

WILLIAM D. HATFIELD NEW PRESIDENT

William D. Hatfield, Decatur, Illinois, was elected to the Presidency of the Federation at the Election Committee Meeting on October 5, 1958. In Dr. Hatfield the Federation has chosen a man with a wealth of operation experience and a noted reputation for his many contributions to the advancement of wastewater treatment techniques. His wide experience with municipal work singularly qualifies him as appropriate for this office with its need for an appreciation of the operations practice advancement program of the Federation.

Dr. Hatfield has been retired officially from the Sanitary District of Decatur since January 31, 1958 after more than 34 years of service. At the Sanitary District's request "Hap" is retained as special consultant. Other consulting work in the wastewater field is now on his schedule also.

Illinois College in Jacksonville was the site of Dr. Hatfield's undergraduate work, where he was awarded a Bachelor of Science degree in 1914 and later he received the Master of Science and Doctor of Philosophy degrees in chemistry from the University of Illinois.

Dr. Hatfield's early professional days were spent with the Illinois State Water Survey (1915–18) as Assistant Chemist and Bacteriologist; Sanitary Corps, USA, 1918–19; Montana State College (1919–20) as Assistant Professor of organic and physical chemistry; and at Highland Park, Mich. (1921–23) as Superintendent of Filtration. In 1924 he began his career with the Sanitary District of Decatur.

He has contributed widely to the technical literature by the publication of many papers dealing with various aspects of wastewater treatment. He has shown, far beyond his primary assignment, a continued interest in wastewater operation and control laboratory methods, and waste recovery. He has been a significant contributor to the joint editorial board of "Standard Methods," and has given his time generously to other committees.

In recognition of his excellent contributions, the Federation in 1945 created the William D. Hatfield Award to recognize outstanding annual sewage works operations reports.

Dr. Hatfield received the Charles Alvin Emerson Medal from the Fed-

eration in 1953. He is also one of the earliest members of the Quarter Century Operators' Club. He has received the Thomas Fitch Rowland Prize and the Rudolph Hering Medal from the American Society of Civil Engineers.

Dr. Hatfield was a Charter Member and was Vice-President (1944) and President (1945) of the Central States Sewage Works Association. He was Director from Central States on the Federation Board of Control (1952–54). At the present time he is active on several committees within the Federation structure.

MARK D. HOLLIS ELECTED VICE–PRESIDENT

Mark D. Hollis, Assistant Surgeon General and Chief Engineer for the United States Public Health Service, and Chief of that Service's Division of Sanitary Engineering Services, was elected to the Vice-Presidency of the Federation at the Election Committee meeting on October 5, 1958.

Mr. Hollis comes to the Federation office with a combination of practical experience and administrative talents in varied fields involving water as a natural resource. His leadership at state, regional, and national levels in seeking expanded cooperative control by government and industry of the country's water pollution problems, and his contact with the research under way in various places to develop newer and more effective ways of coping with water pollution make him sympathetic to the needs of the Federation membership.

A 1931 graduate of the University of Georgia with a Bachelor of Science in Civil Engineering, Mr. Hollis received an Honorary Sc.D. from the University of Florida (1956), and he holds Professional Engineering Registration in the District of Columbia.

Prior to his current appointment in 1948, he had a varied background of experience with the Public Health Service in a number of locations, beginning in 1931. He served as State Engineer with the North Dakota State Health Department from 1934 to 1939, and was commissioned in the regular corps of the Public Health Service in 1940. During the war he served first as Executive Officer and later directed the war-related malaria control operations of the Public Health Service.

In 1947 he was appointed Executive Officer in the Office of the Surgeon General in Washington. He was promoted to his present position of Assistant Surgeon General and Chief Engineer in January 1948. In this capacity he has held several operating posts in the Public Health Service.

Mr. Hollis is a Fellow of the American Public Health Association, and he holds membership in the American Water Works Association, American Society of Civil Engineers, Conference of State Sanitary Engineers, and Conference of Federal Sanitary Engineers.

He is Past President of the National Malaria Society, has served on the Editorial Board of the American Journal of Public Health, and was a member of the Expert Committee on Environmental Sanitation of the World Health Organization. He is currently a member of the Board of Consultants of the National Sanitation Foundation, the American Sanitary Engineering Inter-Society Board, and is Chairman of the Engineering and Sanitation Section of the American Public Health Association. He is also the U. S. Commissioner of the Potomac River Interstate Water Commission.

DETROIT HOSTS THIRTY-FIRST ANNUAL MEETING

For its 31st Annual Meeting, the Federation returned to the motor city of Detroit, after a period of 10 years since the last meeting at this site. The Sheraton-Cadillac Hotel hosted the meeting, October 6–9, where a total of 1,349 registrants were on hand. The registration was second only to the all-time high last year in Boston, where 14 more attended. It is highly significant to note, however, that the 1958 meeting set a record for men's attendance of 1,111. This was some 49 more than were registered at the Boston meeting in 1957.

The 10-year period since the last meeting in Detroit in 1948 has seen a tremendous growth of the Federation as evidenced by the attendance differential. The 1948 meeting was highly successful with 749 present, while the 1958 meeting, with 1,349, represents an increase of 80 per cent.

As usual, the attendance included representatives from a wide geographical area of the United States, Canada, and foreign countries.

An excellent technical program, featuring 10 half-day sessions containing well-balanced material, was a substantial factor in the meeting's success. The desirable location of Detroit was a further attraction. The host, the Michigan Sewage and Industrial Wastes Association, was in a large measure responsible for the success of the meeting, and its Local Arrangements Committee, headed by General Chairman, Clyde L. Palmer, and assisted by Samuel D. Porter as Vice-Chairman, is due a special note of appreciation. The very sincere efforts of the following subcommittee chairmen made possible a well-organized and smoothly-operated meeting: J. E. Cooper, Hotel Arrangements; George E. Hubbell, Finance; Donald M. Pierce, Registration; Michael Groen, Entertainment; Fred H. Burley, Inspection Trips; Milton P. Adams, Local Host; Mrs. Harry Thomas, Ladies' Entertainment; and Carl Walker, Publicity.

President Kenneth S. Watson called the meeting to order Monday morning, Oct. 6. Following the invocation, the Mayor of Detroit, Hon. Lewis C. Miriani, delivered an official greeting to the group. President Watson commented on the Federation activities and growth during the year and pointed out the continuing need for public relations in the sewage and industrial wastes field and the need for more service to the small plant operator. Executive Secretary-Editor Ralph E. Fuhrman, reported that the Federation has again filled out its technical staff and looks forward to an increasingly productive program of service to the membership.

Technical Program

The Detroit Meeting offered the largest technical program ever presented at a Federation meeting. George E. Symons, as Chairman of the Program Committee, and his able

group assembled 10 half-day sessions which provided excellent papers covering a wide range of interests. To provide space for the more than 40 individual papers, forums, panels, symposiums, and discussions, there were four concurrent sessions scheduled during the 4-day period. A symposium on treatment cost reduction was an added feature of particular interest to many in attendance. A late addition to the program was a 5-paper session on synthetic detergents. The program was appropriately well represented by industrial wastes papers. A full session on the petrochemical industry was included, in addition to another half-day grouping of industrial wastes papers, and a special symposium on industry-municipality cooperation. The Research Symposium contained outstanding presentations and the Operator's Forum provided a stimulating session and discussion. The very popular sewer maintenance panel, begun at the Los Angeles Meeting in 1956, was once again offered and was supplemented by a plant maintenance session.

The Laboratory Scientists' Breakfast once again provided an event where those with analytical interests could have open discussion. In all, 40 attended the breakfast session.

In 1957 the industrial wastes group had a breakfast session. This year a new event was the Industrial Wastes Luncheon which nearly 150 attended and heard an address by Dr. W. H. Shuette, Vice-President of Dow Chemical Company, Midland, Mich.

The technical program was as announced in the "Thirty-First Annual Meeting Preview" (see THIS JOURNAL, 30, 9, 1201; Sept. 1958). Technical program papers will appear in the Journal during 1959.

Concurrent Meetings

At the request of other related organizations, in recent years the Federation at its annual meeting has provided the facilities for convenient meeting places for these groups. The press of other meeting schedules has made this concurrent arrangement attractive.

At the Detroit Meeting, the Water Pollution Abatement Committee of the Manufacturing Chemists Association held an all-day meeting on Tuesday. This was the second year this group has met in conjunction with the Federation meeting.

The Conference of State Sanitary Engineers held a breakfast and a meeting of the National Water Policy Committee on Wednesday. More than 20 were present in this group, which met for the first year at the Federation meeting.

The Industrial Wastes Council held a meeting on Monday afternoon at which approximately 20 were in attendance. This is a newly-formed group discussed elsewhere in this report.

Meeting Publicity

For the second year, attention was given to obtaining publicity for the meeting and individuals participating. A press room was kept open throughout the meeting and provided a meeting place for the press to interview speakers, and provided facilities for the use of manuscripts by those interested. In addition to the three Detroit newspapers, representatives of several trade journals used the press room in preparation of copy for publication.

Through the efforts of the Publicity Committee, the Detroit papers carried several stories of the meeting and individual speakers.

A number of releases were prepared for use in the press room and were also given to the wire services.

Entertainment Events

A large attendance was noted at the Family Night Entertainment in the Sheraton-Cadillac Grand Ballroom on

Monday evening. Many favorable comments were received on the thoroughly entertaining evening provided by professional groups.

The Federation Luncheon was a popular event as evidenced by the 150 who attended and heard Robert W. Hartwell, General Manager, Power Reactor Development Company, Detroit, give a very interesting account of the status and problems associated with the Enrico Fermi Atomic Power Reactor under construction near Detroit.

The Annual Federation Awards Dinner in the Grand Ballroom had a capacity crowd of about 700 members and guests. President Watson presented the awards and introduced the new officers. Dancing followed in the same area and attracted a large and enthusiastic group.

Ladies' Entertainment

The Ladies' Entertainment Committee, headed by Mrs. Harry Thomas, provided a full and interesting program for the 238 ladies registered. Headquarters were maintained in the Pan American Room of the Sheraton-Cadillac Hotel. The ladies were guests of the Michigan Sewage and Industrial Wastes Association on Monday morning for breakfast snack and coffee.

A new and stimulating session for the more than 120 ladies in attendance was a round table discussion led by Dr. Morris M. Cohn with its theme of "Random Thoughts on Your Husband's Profession." A high degree of audience participation was in evidence as the ladies discussed freely the public relations aspects of the sewage and industrial wastes field.

An all-day trip to Greenfield Village and Ford Museum on Tuesday was the outstanding event on the ladies' agenda. A large number enjoyed the interesting and authoritative reconstruction of early American life so excellently done at Greenfield Village. In addition to a pleasant luncheon at Lovett Hall, the group had an opportunity to inspect the Ford Museum which contains an exceptional display of early automotive history.

The other tour for the ladies included the chance to see the fabulous civic and convention center under construction on the Detroit waterfront. Lunch was at the Veterans' Memorial Building, also one of the modern attractions of this new development.

Time was allowed for the ladies to shop, visit, play cards, or enjoy activities of their own choosing. A trip to Windsor, Ontario, was offered on Thursday afternoon to complete the busy week.

Inspection Trips

Both industrial waste and sewage treatment facilities were offered to the technical gathering as concurrent inspection trips on Tuesday afternoon. The outstanding Detroit sewage treatment works attracted a large group who were interested in seeing the sewage treatment facilities of a large metropolitan area.

Those with industrial wastes leanings went to the Ford Motor Company Metal Stamping Division at Monroe to see combined water and waste treatment facilities and also went to the same company's Rouge plant to see certain waste treatment operations. At the Monroe plant, both cyanide and chromium plating wastes were treated. At the huge Rouge plant the inspected facilities included treatment for oil removal of contaminated cooling water.

Manufacturers' Exhibits

The Water and Sewage Works Manufacturers Association arranged for the extensive exhibit of new equipment, products, and process development. Exhibits were conveniently located on the same floor, which was the

floor on which the registration facilities and the Grand Ballroom were located. All available space was utilized by the 45 exhibitors and there was a great amount of interest and attention shown by those in attendance.

The number of exhibitors and demand for space again reflect the growth of the Federation. The 1958 number of exhibitors represented a 50 per cent increase over the number in 1948.

DETROIT BOARD OF CONTROL MEETINGS

With Directors representing Member Associations with a total combined membership in excess of 7,000, the 31st Annual Meeting of the Board of Control at Detroit, Michigan, heard reports of Federation progress and determined the course of Federation activities in the year ahead. While membership growth in total numbers was less than the previous year when four new Member Associations were added, the growth was considered satisfactory. At the meeting, the change of Indiana as a part of the Central States Sewage and Industrial Wastes Association to Member Association status was approved, effective November 1, 1958.

The Board of Control approved many committee recommendations during both the October 5 and the October 9 meetings. Among the important actions were the following:

(1) An Interim Committee which met between Board Meetings reported on the desirability of a Federation name change. At the second Board Meeting the committee reported its deliberations and the Board approved the recommendation that such a committee give the matter active consideration with the expectation that definite recommendations would be made to the Board in October 1959.

(2) The Board approved a recommendation of the Organization Committee that new Federation Member Associations have a minimum number of 15.

(3) A program for increased Federation activity in (a) professional advancement, and (b) public relations was proposed by the Executive and Finance Committees. While these activities were authorized for 1959 with a budget that will require a transfer from reserve funds, the Board, after a long and detailed discussion, voted to adopt this program and finance it by an increase in membership dues, effective January 1, 1960. At that time, active membership dues in the Federation will increase from $5 to $8 per year and Corporate membership dues in the Federation will increase from $10 to $15 per year. At the same time non-member subscriptions will be advanced from $7.50 to $10 per year, while single copies of the Journal will increase from $1 to $1.25. There was general agreement that rising costs along with these new activities made such a revision in financing mandatory.

(4) A resolution was passed urging dissolution of the Joint Committee on Advancement of Sanitary Engineering, composed of representatives of FSIWA, ASCE, AWWA, APHA, and ASEE recommending transfer of the members to the American Sanitary Engineering Intersociety Board. Approval of this resolution by the Board paralleled a similar action by the AWWA Board of Directors.

(5) The Board of Control approved the resolution submitted to give vigorous support to the revision of the Water Pollution Control Act. This resolution supports additional construction grant funds by the Federal Government and it urges an over-all increase in funds as well as a maximum allotment available per project. It was recognized that this program had given a genuine impetus to sewage treatment plant construction during

recent years. The Board directed that the resolution be presented to those who will be concerned in the future consideration of this legislation.

(6) Two additional subcommittees of the Sewage and Industrial Wastes Practice Committee were authorized. These subcommittees will be concerned with (1) fringe area sanitation, and (2) current developments on sludge digestion.

Special Honors

As a particular highlight of the Awards Dinner, special honors were conferred on two men who have given meritorious service to the Federation since its early days. The accompanying photographs show Floyd W. Mohlman and W. W. DeBerard, respectively, being honored in presentations by President Watson at the Awards Dinner.

The Federation, in recognition of 30 years of service to the JOURNAL as Editor from its beginning in 1928 to 1943, and as Advisory Editor since 1944, conferred on Dr. Mohlman a beautiful, engraved silver bowl as a permanent piece and a framed certificate for wall use.

In the other signal honor the Federation designated Mr. DeBerard as Treasurer Emeritus in grateful recognition of his distinguished and faithful service as Treasurer for the period from January 1941 to October 1958 and awarded him a very attractive two-pen desk set and a framed certificate for wall display.

Dr. Mohlman was further honored when the German Association (Abwasser-technische Vereinigung) conferred honorary membership on him in their organization and presented through President Watson a handsome leather-bound testimonial certificate recognizing his many significant contributions of international interest to the field of wastewater treatment.

1958 Awards

The following honors and awards, as conferred by the Board, were presented or announced by President Watson at the Annual Awards Dinner on October 8:

Elected to Honorary Membership were E. Sherman Chase of Boston, Mass., partner in the firm of Metcalf and Eddy; and George J. Schroepfer, Professor of Sanitary Engineering at the University of Minnesota. Both men are Past Presidents of the Federation and along with their outstanding contributions to the Sanitary Engineering profession have found time to give to many Federation activities.

The Harrison Prescott Eddy Medal for outstanding contribution in research was awarded to W. E. Budd and George F. Lambeth for their work as presented in the paper, "High-Purity Oxygen in Biological Sewage

Treatment" (THIS JOURNAL, **29**, 3, 237; Mar. 1957).

The George Bradley Gascoigne Medal for operational contributions was earned by Dean M. Taylor, Sanitary Engineer at the Little Miami Works in Cincinnati, Ohio, for his paper, "Sludge Conditioning and Filtration at Cincinnati's Little Miami Sewage Works" (THIS JOURNAL, **29**, 12, 1333; Dec. 1957).

The Industrial Wastes Medal was given to H. W. Bialkowsky and P. S. Billington for their work at the Pulp Division of Weyerhaeuser Timber Company in Longview, Wash., as reported under the title, "Pilot Studies to Predict Effects of Waste on Receiving Waters" (THIS JOURNAL, **29**, 5, 551; May 1957).

The Charles Alvin Emerson Award went to Gail P. Edwards in recognition of his many and important contributions to the science of sewage treatment through his activity and leadership as member, vice-chairman, and chairman of the Standard Methods Committee and as a member of the Joint Editorial Board of *Standard Methods for the Examination of Water, Sewage, and Industrial Wastes*, and of his many other services in advancing the basic purposes of the Federation.

Nominations for the 1958 Arthur Sidney Bedell Awards, for service to Member Associations of the Federation, were confirmed by the Board as follows: C. W. Oxford (Arkansas); Raymond R. Ribal (California); C. S. Anderson (Canada); C. C. Larson (Central States); Ralph H. Baker (Florida); H. S. Allen (Iowa); F. W. Allen (ISP, England); S. Leary Jones (Kentucky-Tennessee); Donald M. Pierce (Michigan); V. J. Lechtenberg (Nebraska); Robert S. Shaw (New Jersey); Uhl T. Mann (New York); George S. Rawlins (North Carolina); (Pacific Northwest)*; Roy F. Weston (Pennsylvania); T. E. Robertson (South Carolina); Elof Ljungholm (Sweden); and Roger Moehlman (Texas).

Nominations for the 1958 William D. Hatfield Awards, for outstanding sewage treatment plant operation, were confirmed by the Board as follows: Dan Millender (Arkansas); Melvin F. Klemmick (California); Charles Hicks (Canada); Daniel J. Raye (Florida); M. F. Neuzil (Iowa); W. T. Blackman, Sr. (Kentucky-Tennessee); Stanley J. Mogelnicki (Michigan); Loren Brannen (Nebraska); William S. Applegate (New Jersey); John O. Laird (New York); John L. Brown (North Carolina); (Pacific Northwest)*; Paul N. Longley (Pennsylvania); Frank M. Gibson (South Carolina); Carl Alm (Sweden); and S. L. Allison (Texas).

* Nominee selected, secrecy requested.

Membership

The Secretary reported that the combined Honorary, Active, and Corporate membership of the Associations comprising the Federation reflected continued growth to another new high of 8,206 on September 30, 1958, a gain of 526, or 6.9 per cent, for the year. Some large gains in membership were made within several Member Associations. Very few losses were reported. Twenty-five groups showed increases, while 14 showed small losses, and 3 remained the same.

The total number of Associate Members remained at 78 as of September 30, 1958.

The host Michigan Association won the numerical increase contest with a notable list of 146 new members, while the aggressive Florida Association, which won the previous year, produced a second place number of 93. Last year's second place winner, the Canadian Institute, took third place (44).

The Puerto Rico Association was awarded the percentage increase prize, showing a net gain of 74.5 per cent. The Dakota Association was second

with 46.9 per cent, and Michigan was third with 33.7 per cent, respectively.

As of September 30, 1958, the number of Member Associations remained the same as 42, with one petition on hand for board action.

Financial

The operating budget for fiscal 1959 is set at $152,700, a substantial increase of $29,500 over the previous year. Increased printing and distribution costs plus anticipated staffing increases make this necessary. To balance the operating budget a transfer of $13,700 from reserves is anticipated.

Audited net worth of the Federation at the end of 1957 was $93,551.01; a modest increase over 1956.

Seattle in 1963

The Meeting Place Committee recommended, and the Board approved, Seattle, Washington, as the official 1963 meeting place. The meeting will be October 6–10, 1963, at the Olympic Hotel. Previously announced and approved meeting sites are:

1959, Dallas, Texas, Hotel Statler-Hilton, Oct. 11–15.
1960, Philadelphia, Pa., Philadelphia-Sheraton, Oct. 2–6.
1961, Milwaukee, Wis., Schroeder Hotel, Oct. 9–12.
1962, Toronto, Canada, Royal York Hotel, Oct 8–11.

Invitations are on hand from the following Member Associations; Florida (Miami Beach), Missouri (Kansas City or St. Louis), Ohio (Cincinnati), Nebraska and Rocky Mountain (Denver), Pennsylvania (Pittsburgh), New Jersey (Atlantic City), and Texas (Dallas).

Bedell and Hatfield Award Nominations

The accompanying schedule of Bedell and Hatfield Award nominations was approved by the Federation Board of Control on October 5, 1958. The award schedule is included for the current three-year period. Those Member Associations with changes in membership which place them in a different category for award eligibility are included in the future schedule.

Art Niles Elected Treasurer

At the meeting A. H. Niles, Federation President 1949–50, was elected Treasurer of the Federation for the coming year. Mr. Niles, who is Commissioner of Sewage Disposal for Toledo, Ohio, has been a regular participant in Federation activities.

Director-At-Large

Clair N. Sawyer, Associate and Director of Research, Metcalf and Eddy, Boston, Mass., was elected Director-At-Large for the term October 1959 to October 1961.

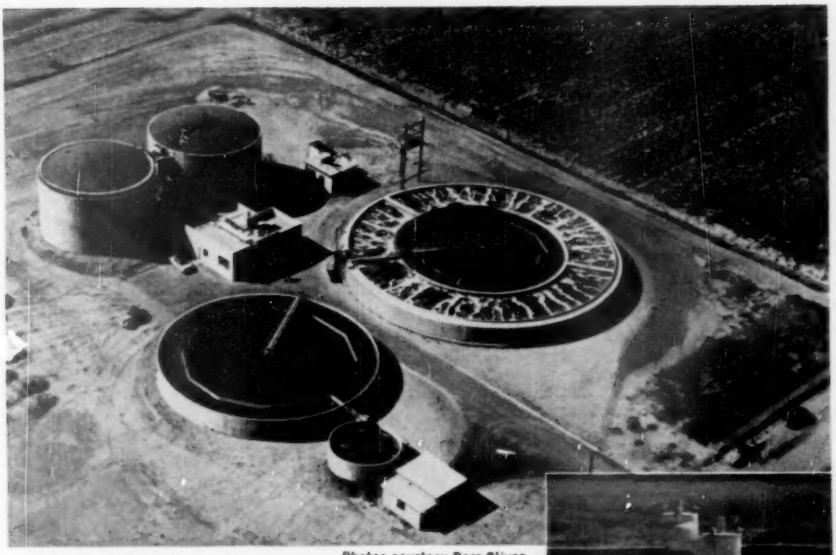
Bedell and Hatfield Award Schedule

(Date of Award is year submitted to Board of Control)

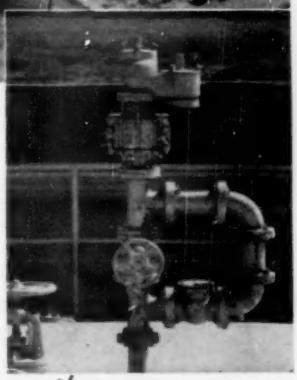
Member Association	Members		Nominations Per 3 Years	Future Schedule*		
	9-30-57	9-30-58		1959	1960	1961
Alabama	51	56	1	—	✓	—
Arizona	42	43	1	—	✓	—
Arkansas	50	46	1	—	—	✓
California	650	640	3	✓	✓	✓
Canadian Institute	562	606	3	✓	✓	✓
Central States	711	734	3	✓	✓	✓
Dakota (North & South)	32	47	1	✓	—	—
Federal	80	86	1	—	—	✓
Florida	359	452	2	—	✓	✓
Georgia	98	91	1	✓	—	—
Germany	40	40	1	—	✓	—
Iowa	124	126	1	—	—	✓
IPHE (England)	29	25	1	—	✓	—
ISP (England)	122	129	1	—	—	✓
Israel	20	20	1†	—	✓†	—
Kansas	180	181	1	—	✓	—
Kentucky–Tennessee	183	197	1	—	—	✓
Louisiana	17	15	1†	—	—	✓†
Maryland–Delaware	75	71	1	✓	—	—
Michigan	433	579	3	✓	✓	✓
Mississippi	1	73	1	—	✓	—
Missouri	61	66	1	—	✓	—
Montana	36	35	1	✓	—	—
Nebraska	66	61	1	—	—	✓
New England	400	406	2	✓	✓	—
New Jersey	326	322	2	—	✓	—
New York	640	644	3	✓	✓	✓
New Zealand	—	30	1	—	✓†	—
North Carolina	174	163	1	—	—	✓
Ohio	401	431	2	✓	✓	—
Oklahoma	60	45	1	✓	—	—
Pacific Northwest	335	345	2	—	✓	✓
Pennsylvania	523	505	3	✓	✓	✓
Puerto Rico	55	96	1	✓	—	—
Rocky Mountain	111	104	1	✓	—	—
South Carolina	45	47	1	—	—	✓
Sweden	104	110	1	—	—	✓
Swiss	17	17	1†	—	✓†	—
Texas	216	258	2	✓	—	✓
Utah	26	40	1	—	✓	—
Virginia	130	137	1	✓	—	—
West Virginia	95	87	1	✓	—	—
Totals	7,680	8,206		18	21	20

* Year eligible to petition for nominations.

† Schedules for 1960 and 1961 based on membership as of Sept. 30, 1958.



Photos courtesy Dorr-Oliver



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S-16

Proceedings of Member Associations

MICHIGAN SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The Michigan Sewage and Industrial Wastes Association held its 33rd Annual Conference at the Charlevoix Beach Hotel, Charlevoix, Mich., June 23–25, 1958.

The Conference, with a record attendance of 298, was opened with a resume of news from the field by D. M. Pierce, Sanitary Engineer, Michigan Department of Health. At the same session Robert McCauley, Professor of Sanitary Engineering, Michigan State University, discussed "The Development and Use of Design Standards for Sewerage Systems," and Kenneth Fishbeck, Consulting Engineer, Lansing, Mich., discussed "Some Problems and Trends in Sewer Construction Maintenance and Materials."

One of the sessions was devoted to a popular question box panel discussion, moderated by Huntley DeLano, Superintendent of Sewage Treatment, Grand Rapids. Participating were: R. A. Greene, Superintendent of Sewage Treatment, Jackson; Russell Johnson, Sanitary Engineer, Michigan Department of Health; John P. Hennessey, Superintendent of Sewage Treatment, Pontiac; Archie Mark, Superintendent of Sewage Treatment, Vassar; and F. W. Galarno, Superintendent of Sewage Treatment, Saginaw.

There were also panel discussions on "Brewery Wastes Disposal at Frankenmuth," and on the "Recommended Units of Expression for Design and

(*Continued on page 506a*)

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Operation of Sewage and Industrial Wastes Treatment Plants."

Other papers of interest included:

"Sewerage and Grand Rapids Industries," Mrs. Doris Voshel, Chemist, Grand Rapids Sewage Treatment Plant.

"How Industries Have Solved Their Wastes Problems," by Robert Brink, Industrial Wastes Engineer, Buick Motor Division, General Motors Corporation, and Eldred Hall, Fletcher Paper Company.

"Putting Safety Into Your Operations," by M. E. Peacock, Public Works Assistant, City of Saginaw.

Ralph E. Fuhrman, Executive Secretary of the Federation of Sewage and Industrial Wastes Assns., presented the Bedell Award to Robert A. Greene, Jackson, and the Hatfield Award to J. C. Marshall, Charlevoix.

The following officers were elected:

(*Continued on page 508a*)

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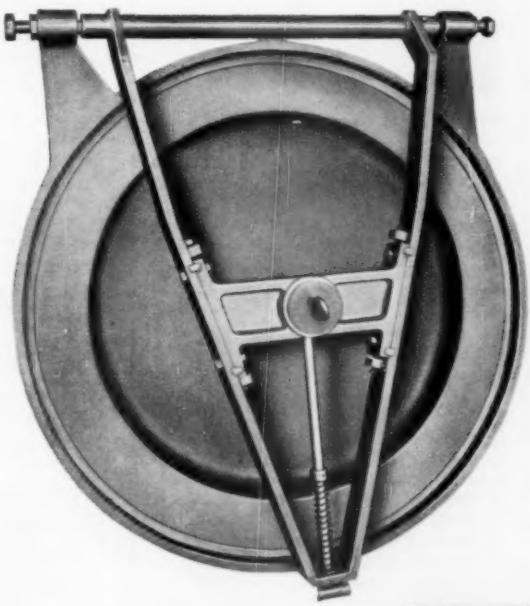

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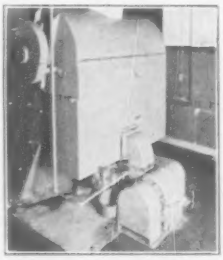

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PENNSYLVANIA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 30th Annual Conference of the Pennsylvania Sewage and Industrial Wastes Association was held at The Pennsylvania State University, University Park, Pa., on August 13–15, 1957, and 216 persons attended.

Highlights of the meeting included a Sewage Operators' Round Table and an Industrial Wastes Round Table. A Control Analysts' Breakfast proved to be extremely successful; it was set up for about 18 participants and had to be moved into another room because 56 interested men turned up!

FSIWA Vice-President, W. D. Hatfield, attended the meeting to extend the greetings of the Federation and to present the Bedell Award for extraordinary personal service to the Pennsylvania Association to Howard T. Reuning, Ridgway, Pa., and the Hatfield Award for an outstanding annual sewage works operation report to King H. Hendrickson of Beaver Falls, Pa.

The following officers were elected:

President: Harry W. McElhaney, Meadville.
First Vice-President: Samuel I. Zack, Harrisburg.
FSIWA Director (1961): Bernard S. Bush, Wilkes-Barre.
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(Continued through page 516a)

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INDEX TO ADVERTISERS

	Page
American Brass Company	496a
American Cast Iron Pipe Company	505a
American Concrete Pressure Pipe Association	497a
Armco Drainage and Metal Products, Incorporated	507a
B-I-F Industries, Incorporated	Inside Front Cover
Cast Iron Pipe Research Association	486a, 487a
Chicago Pump Company	479a
Combustion Engineering (Raymond Division)	481a
Dorr-Oliver Incorporated	502a
Filtration Equipment Corporation	506a
Flexible Incorporated	518a
Gruendler Crusher and Pulverizer Company	508a
Homestead Valve Manufacturing Company	493a
Inertol Company, Incorporated	488a
Infilco Incorporated	485a
Johns-Manville	490a, 491a
Lock Joint Pipe Company	Inside Back Cover
Nichols Engineering and Research Corporation	498a
Pacific Flush Tank Company	500a
Portland Cement Association	492a
Simplex Valve and Meter Company (Subsidiary of Pfaudler Permutit Incorporated)	483a
United States Pipe and Foundry Company	494a, 495a
Vapor Recovery Systems Company	503a
Walker Process Equipment Incorporated	489a
Wallace and Tiernan Incorporated	Back Cover
Wedge-Lock Clay Pipe Manufacturers, Incorporated	499a
Western Machinery Company	504a

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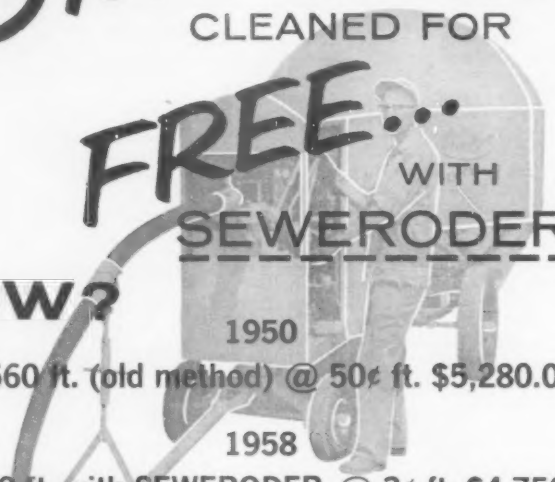

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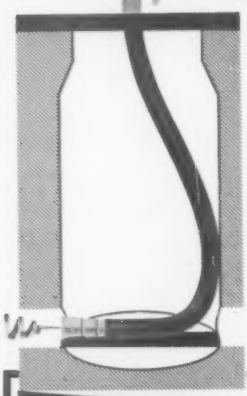

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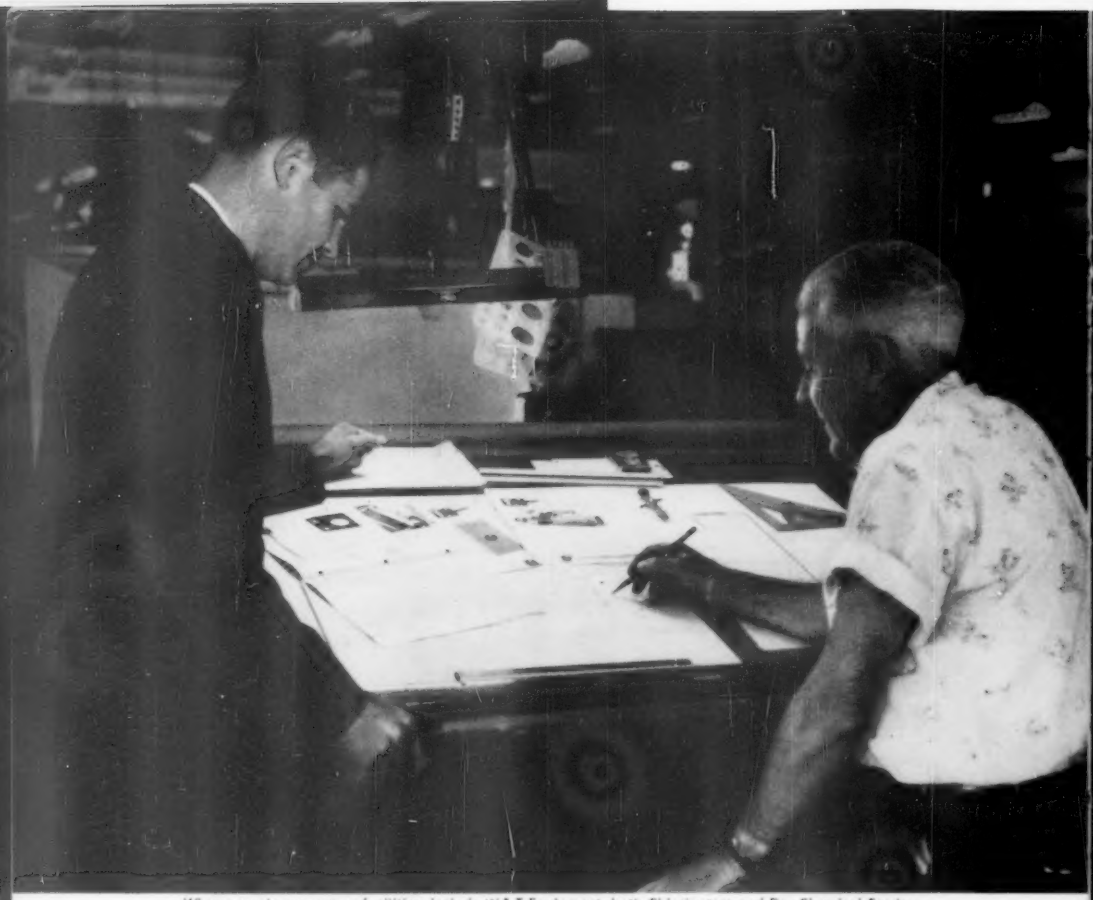

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